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TRANSPORTATION RESEARCH COMMAND

FORT EUSTIS, VIRGINIA

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**UNITED STATES ARMY AVIATION  
CRASH INJURY RESEARCH**

**Final Report**

**U.S. ARMY TRECOM Contract DA-44-177-TC-707**

**16 December 1960 to 15 September 1961**

*TREC Technical Report 62-13*

**prepared by :**

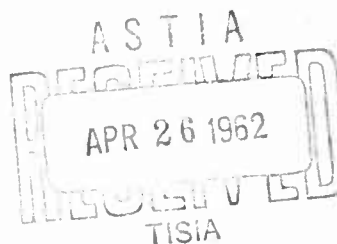
**AVIATION CRASH INJURY RESEARCH**

**PHOENIX, ARIZONA**

**A DIVISION OF**

**FLIGHT SAFETY FOUNDATION, INC.**

**NEW YORK, NEW YORK**



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September 1961

UNITED STATES ARMY AVIATION  
CRASH INJURY RESEARCH

FINAL REPORT

under

U. S. ARMY  
TRANSPORTATION RESEARCH COMMAND  
Contract DA-44-177-TC-707  
Task 9R95-20-001-01

16 December 1960 to 15 September 1961

AvCIR 61-20

Prepared by  
Aviation Crash Injury Research  
A Division of  
Flight Safety Foundation, Inc.  
2871 Sky Harbor Blvd.  
Phoenix, Arizona

for  
U. S. ARMY TRANSPORTATION RESEARCH COMMAND  
FORT EUSTIS, VIRGINIA

HEADQUARTERS  
U. S. ARMY TRANSPORTATION RESEARCH COMMAND  
TRANSPORTATION CORPS  
Fort Eustis, Virginia

F O R E W O R D

This report was prepared by Aviation Crash Injury Research, a division of the Flight Safety Foundation, Inc. (FSF) under the terms of Contract DA 44-177-TC-707. All work was accomplished between 16 December 1960 and 15 September 1961 and is being related according to individual Work Items.

Views expressed in the report have not been approved by the Department of the Army; however, conclusions and recommendations contained therein are concurred in by this Command.

The work performed under this contract encompassed the following:


1. Crash injury investigations of selected military and civilian aircraft accidents;
2. Collection of data pertaining to crash safety design criteria;
3. Review of military specifications and evaluation of Army aircraft, mockups, and proposed designs;
4. Consideration of the feasibility of special equipment to perform dynamic crash tests;
5. Study of crash safety equipment and procedures;
6. Conduct of statistical and clinical analyses of accident data for both military and civilian aircraft collected from Military, Federal, and State Aviation Agencies;
7. Liaison with groups and agencies concerned with aircraft Crash Injury and Crashworthiness programs;
8. Specialized courses in crash injury investigation for the training of Army personnel;
9. Determination of techniques available for remote control of an H-21 helicopter into a crash configuration;




10. Dynamic crash tests of two H-25 and two H-13 helicopters;  
and
11. Delineation of procedures for investigating causes of crash  
and postcrash fires through integration with the crash test  
program.

FOR THE COMMANDER:

APPROVED BY:

  
WILLIAM J. NOLAN  
USATRECOM Project Engineer

  
EARL A. WIRTH  
CWO-4 USA  
Adjutant

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The Office of the Surgeon General, Department of the Army, contributed much by the assignment of James D. Davenport, Lt. Colonel, MSC, to the project and by the later assignment of Lloyd Spencer, Captain, MSC, as a replacement.

USATRECOM also contributed greatly by the detailing of a Flight Surgeon, Daniel J. Schneider, Captain, MC, to the activity. This is the first time that a professional medical specialist has been affiliated with the project full time.

The United States Army Board for Aviation Accident Research contributed extensively by their close cooperation in all fields of endeavor, particularly in providing the breakaway fuel tank system for use in the full-scale crash test program.

## SUMMARY

During this year of the program of Army Aviation Flight Safety, added emphasis was given to full-scale dynamic crash testing of aircraft and intensive activities were carried on in statistical analysis, while at the same time continuing the work in the training of crash injury investigators and field investigation of Army aircraft accidents. Definite accomplishments can be reported in all Work Items.

1. Because of the character of aircraft accident experience during this period, only two accidents were investigated which would fall into the normal framework of crash injury investigation. One was an accident involving a U. S. Army H-21C Vertol Shawnee helicopter at Tobyhanna, Pennsylvania, on 23 August 1961. The other involved a U. S. Army G-91 Reconnaissance Jet Fighter at Fort Rucker, Alabama, on 1 February 1961. However, two other U. S. Army accidents were investigated because of special circumstances and the Army's desire to have the assistance of the special skills of AvCIR's investigators.

These were:

- a. U. S. Army G-91 Reconnaissance Jet Fighter Accident, Fort Rucker, Alabama - 27 July 1961; and
- b. U. S. Army HU-1A Bell Helicopter Accident, Fort Carson, Colorado - 10 August 1961.

One other accident involving a U. S. Army aircraft was reported upon under this contract, although it was investigated under USATRECOM Contract DA 44-177-TC-624. This involved a National Guard H-23C helicopter at Phoenix, Arizona, on 8 December 1960.

In the civilian field, only one accident was investigated and this was done not to study crash injury but to study evacuation and survival under conditions of postcrash fire. This was the United Airlines DC-8 Transport accident at Stapleton Airport, Denver, Colorado, on 11 July 1961.

2. Work continued on an illustrated manual dealing with "Crash Safety Design Criteria"; major subdivisions will deal with

(1) Crashworthiness, (2) Restraint Systems (Occupant and Equipment), (3) Occupant Environment, (4) Crash Force Energy Absorption, and (5) Postcrash Factors.

Publication of a new series of "Design for Safety" memos was initiated. Each memo will treat a separate design detail related to crash injury and/or survival.

3. Accident investigations and full-scale crash tests added to the engineering background needed to evaluate Military Specifications covering troop seats, crew seats, litter installations, and seat belt and shoulder harness installations.

Attention was also given to design evaluations of U. S. Army HU-1B helicopter and Type Specification for Light Observation Helicopter (Army).

4. Since full-scale crash testing of aircraft does not satisfy the need for routine, continuous dynamic testing of the characteristics of many different aircraft and their components, a need for special equipment - a dynamic testing device - is indicated. However, the feasibility, or availability, of such a device needed to be investigated especially as it applies to true simulation of aircraft accidents with forces being experienced in three planes and with varying rates of onset and time phases. Among existing dynamic testing devices, none were found to be entirely adequate so a study to determine what would be involved in the development of a satisfactory device was indicated. A specification that defined the desired dynamic testing conditions was prepared and submitted to a group of engineering firms for competitive bid.
5. One of the new experimental APH-5 crash helmets was used in the full-scale crash test of an HUP-2 helicopter with extensive damage to the helmet being sustained; the helmet currently is being subjected to comparable crash forces under controlled conditions by Dr. Snively of the Snell Memorial Foundation. Study on the protective limits of seat belt protection indicated some of the injuries that may be expected when the tolerable and injurious limits of seat belt protection are exceeded.
6. Four detailed statistical studies were completed and reported upon, namely:
  - a. Injury Severity as Related to Seat Tiedown and Belt Failure in Lightplane Accidents, TREC Technical Report 61-96;



- b. Prediction of Degree of Injury from Impact and Damage Variables in Lightplane Accidents, TREC Technical Report 61-94;
  - c. Factor Analysis of Lightplane Accident Impact and Damage Variables, TREC Technical Report 61-122; and
  - d. Relationship Between Impact Variables and Injuries Sustained in Lightplane Accidents, TREC Technical Report 61-95.
7. Three symposia of significance to the work were attended by staff:
- a. Symposium of Biomechanics of Body Restraint and Head Injury conducted at the Naval Air Materiel Center, Philadelphia, Pennsylvania, June 14-15, 1961;
  - b. Aerospace Medical Panel of the Advisory Group for Aeronautical Research and Development (AGARD), conducted at Oslo, Norway, 24-29 July 1961; and
  - c. Twelfth Meeting of the Emergency Egress Committee (U. S. Navy) at Lockheed Aircraft Corporation, Burbank, California, 16-17 August 1961.
8. Three special training courses, each of two weeks' duration, in the field of aviation crash injury investigation were held. Forty military students attended; of these, eighteen were flight surgeons or aviation medical officers, sixteen were aviation safety officers, and six represented research, development, and procurement activities.
9. Tasks related to crash injury developed during the contract period included:
- a. Study of possible ways of crashing a helicopter from flight through the use of a remote control system; and
  - b. Development, production, and crash testing of a new-type troop seat with built-in energy absorption.
10. As a continuation of the program of dynamic testing of aircraft and their components, inaugurated with the drop of an H-25 helicopter from a moving crane, in October 1960, four additional helicopters were crashed using the same technique and comparable

configurations. Two were HUP-2 helicopters, the U. S. Navy version of the H-25, and two were H-13 Bell helicopters. A primary purpose of these additional crash tests was to establish a pattern of repeatability of test results; however, they also permitted a degree of experimentation with a number of design and installation changes indicated as desirable in the initial drop of the H-25. In addition, they permitted some refinement in test techniques.

11. Investigation was carried out on the postcrash fire problem, and previous research on both crash-fire inerting systems and crash resistant flammable fluid systems was reviewed and evaluated. From this, recommendations were made covering a postcrash fire research program with initial attention to rotary wing aircraft.

FIELD INVESTIGATION OF ACCIDENTS

Because of the character of aircraft accident experience during this period, only two accidents were investigated which would fall into the normal framework of crash injury investigation. One was an accident involving a U. S. Army H-21C Vertol Shawnee helicopter at Tobyhanna, Pennsylvania, on 23 August 1961. The other involved a U. S. Army G-91 Reconnaissance Jet Fighter at Fort Rucker, Alabama, on 1 February 1961. However, two other U. S. Army accidents were investigated because of special circumstances and the Army's desire to have the assistance of the special skills of AvCIR's investigators. These were:

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In the civilian field, only one accident was investigated, and this was done not to study crash injury but to study evacuation and survival under conditions of postcrash fire. This was the United Airlines DC-8 Transport accident at Stapleton Airport, Denver, Colorado, on 11 July 1961.

U. S. ARMY H-21C SHAWNEE HELICOPTER ACCIDENT - 23 August 1961 (TREC Technical Report 61-134\*, AvCIR Report 61-11, September 1961.)

This accident occurred in a heavily wooded area while the aircraft was engaged in a search mission. While flying in marginal weather conditions at a low altitude, the pilot of this aircraft became disorientated, lost control of the aircraft, and crashed into trees. During the crash sequence, the aircraft with the nose down in an extreme attitude and yawing to the left struck a very large tree on the

\* U. S. Army Transportation Research Command, Fort Eustis, Virginia.

## WORK ITEM 1

pilot's side. At impact, the pilot was thrown clear of the aircraft. The nose then dropped to the ground; the fuselage pivoted to the right with the tail pylon striking boulders. The aircraft came to rest inverted, whereupon the copilot immediately released his seat belt and shoulder harness and evacuated through the unobstructed front right cockpit. The crew chief, seated next to the fuselage cargo door and restrained by his safety belt in an inverted position, released himself and evacuated through the open cargo door. After evacuation of the aircraft, the copilot realized that the engine was still operating and returned to stop the engine. The pilot received fatal injuries; the copilot received minor contusions and abrasions; and the crew chief received minor contusions.

The fuselage received very little damage, and the tail pylon sheared off from striking boulders. The main concentration of force was on the right front cockpit area - the occupiable area being reduced by approximately 65 percent during penetration by the forward transmission and rotor head.

From the investigation it was concluded that since the occupiable area of the pilot had been reduced approximately 65 percent, survival by the pilot would have been questionable had he remained in the cockpit. The pilot seat attachments failed at all four connecting points due to impact forces. The copilot seat attachments failed at two points but the seat and occupant remained in place.

The investigation also found that the crew chief remained strapped to his seat but received minor contusions due to his being thrown against the installed litter supports and being struck by chock blocks that had not been properly secured.

As a result of these and other findings, the following recommendations were made:

1. The seat tiedown structures of the pilot and copilot seats in the H-21 should be redesigned to prevent failures under survivable crash force applications, and the occupant restraint devices (seat belt and shoulder harness) should be anchored to the primary structure.
2. The transmission support structure in this type aircraft should be designed to prevent the transmission from being displaced into the occupiable area of the cockpit during

1

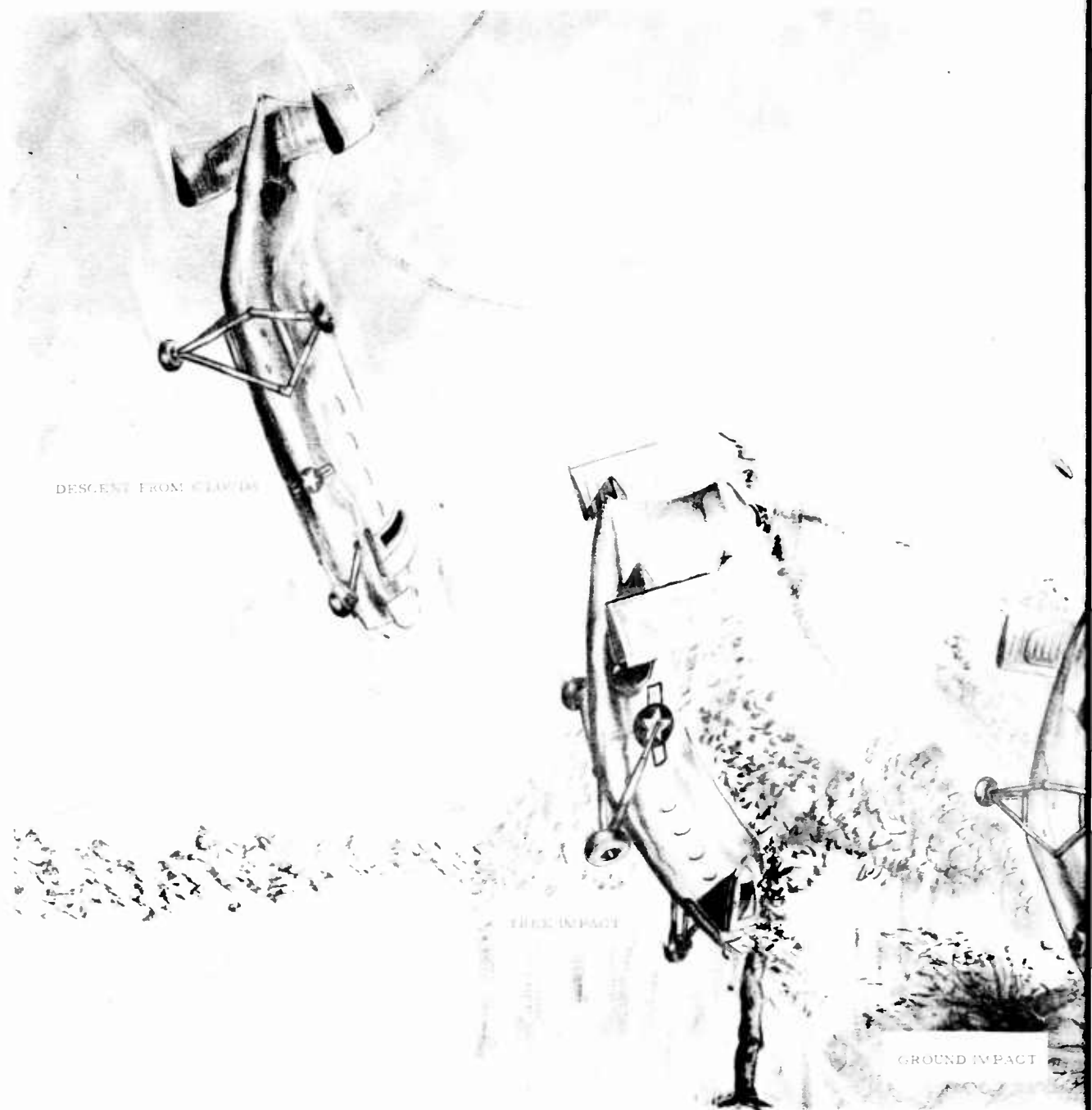


Figure 1. Kinematics of Crash Sequence of H-21C

2



Diagram of Crash Sequence of H-21C, Tobyhanna, Pennsylvania.

moderate crash forces.

3. Every effort should be made in the design of future aircraft to route the drive shafts outside the occupiable areas.
4. Consideration should be given to the use of an improved chin-strap attachment as a modification to the APH-5 crash helmet.
5. A nonshattering material should be utilized for sun visors on the APH-5 helmet.
6. Litter brackets should be redesigned so that they can be stowed flush with the cabin wall when not in use.
7. Crew members and passengers again should be made aware of the potential hazards of loose equipment within the occupiable areas of an aircraft.

G-91 RECONNAISSANCE JET FIGHTER ACCIDENT - 1 FEBRUARY 1961 - TREC Technical Report 61-91, July 1961

This accident occurred while the aircraft was returning from a training mission. The turn to final approach was made too wide and the aircraft overshot the runway. An attempt to go around failed and the aircraft crashed in a wooded area 1/4 mile short of the runway.

While at an altitude of approximately 200-300 feet, the pilot started to eject and then changed his mind.

The aircraft touched down on the tail skid in a nose-high attitude and a right yaw, sliding 28 feet before the main landing gear touched the ground. The right gear collapsed, and after approximately 20 feet the nose wheel was torn free. The aircraft slid another 25 feet on the underside of the airscoop and bounced, becoming airborne again. It then hit several trees, broke into two sections, and the aft section burst into flames.

The pilot died 3 days after the accident, the fatal injury being caused by a blow to the head. It was judged that this occurred when the pilot's head was thrown so that it projected over the side of the

## WORK ITEM 1

cockpit as the aircraft went through the trees, resulting in a heavy blow on the front of the APH-5 crash helmet.



Figure 2. G-91 Reconnaissance Jet Fighter Accident.

The investigation resulted in several significant conclusions and recommendations:

1. The cockpit structure, by remaining relatively intact, provides a good crashworthy environment.
2. The ejection seat, designed to provide safe escape at all altitudes and speeds, should be utilized as an escape device except possibly when crash-landing on a well-prepared surface or runway.
3. Further study should be given to the effectiveness of the APH-5 helmet, particularly to the effects of improper sizing or fitting.

U. S. ARMY G-91 RECONNAISSANCE JET FIGHTER ACCIDENT -  
27 JULY 1961, Memorandum Report, AvCIR 61-12, September 1961

This accident involved a U. S. Army G-91 reconnaissance jet fighter which crashed during an experimental takeoff at Fort Rucker, Alabama.



## WORK ITEM 1

A four-bottle JATO take-off was initiated on a water-covered runway. Shortly afterward the aircraft assumed an excessive nose-high attitude; the tail skid appeared to be dragging the ground. This attitude seemed to increase after take-off until at the end of the JATO burnout, at a few hundred feet altitude, the aircraft was in an extremely nose-high attitude. Falling over the left wing in what resembled a typical "swept-wing" stall, the aircraft lost altitude and suddenly reversed bank, striking the ground with the right wing past the vertical position. The aircraft burst into flames and disintegrated.

Fire and rescue teams, at the crash site within seconds after the accident, found the pilot, still strapped to the detached ejection seat, lying on the ground. The fatal injuries were generalized as multiple extreme. The cockpit canopy was found nearby with indications that an ejection had been attempted.

Investigation of the accident was conducted by the U. S. Army Aviation Board. Movie camera coverage of the take-off supplied sequence of events data.

Crash injury analysis of this accident was not made by the AvCIR staff due to investigation by the U. S. Army Aviation Board and the nonsurvivable nature of the accident; consequently, no recommendations were made and the report was presented in memorandum form only.

U. S. ARMY HU-1A BELL IROQUOIS HELICOPTER ACCIDENT,  
10 AUGUST 1961, TREC Technical Report 62-10\*, AvCIR Report  
61-13, September 1961.

This accident occurred in mountainous terrain while the aircraft was engaged in the transportation of military personnel.

An approach by the aircraft was made over the intended landing site adjacent to a small lake; then, in maneuvering in a left, descending turn onto the final approach, the pilot apparently lost control and the helicopter struck a boulder on the bank of the lake.

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\* U. S. Army Transportation Research Command, Fort Eustis, Virginia.

## WORK ITEM 1



Figure 3. HU-1A Helicopter Accident Site, Fort Carson, Colorado.

Army personnel arrived at the scene of the crash to find the wreckage partially submerged at the edge of the lake. The pilot was found in front of the wreckage with fatal impact injuries. The copilot, still strapped in the seat, was found, expired, floating in the lake. Later autopsy revealed a lacerated aorta. One lifeless passenger was found between the wreckage and the shore. A second lifeless passenger had been trapped in the submerged wreckage.

Examination of the wreckage revealed definitely nonsurvivable conditions for the pilot and copilot and showed only slightly better conditions for the passengers who were compressed between the crushed floor and aft bulkhead. Due to patterns of restraint system failures and other findings, the following recommendations were made:

1. The cast fittings in the occupant tiedown chain should be replaced with materials possessing high-percentage elongation properties. Stock materials such as 2017 aluminum, 4130 chrome-molybdenum steel, and 301 stainless steel, offer much better elongation values combined with reasonable strength-to-weight ratios.



Figure 4. HU-1A Helicopter Accident Kinematics,  
Fort Carson, Colorado.

WORK ITEM 1

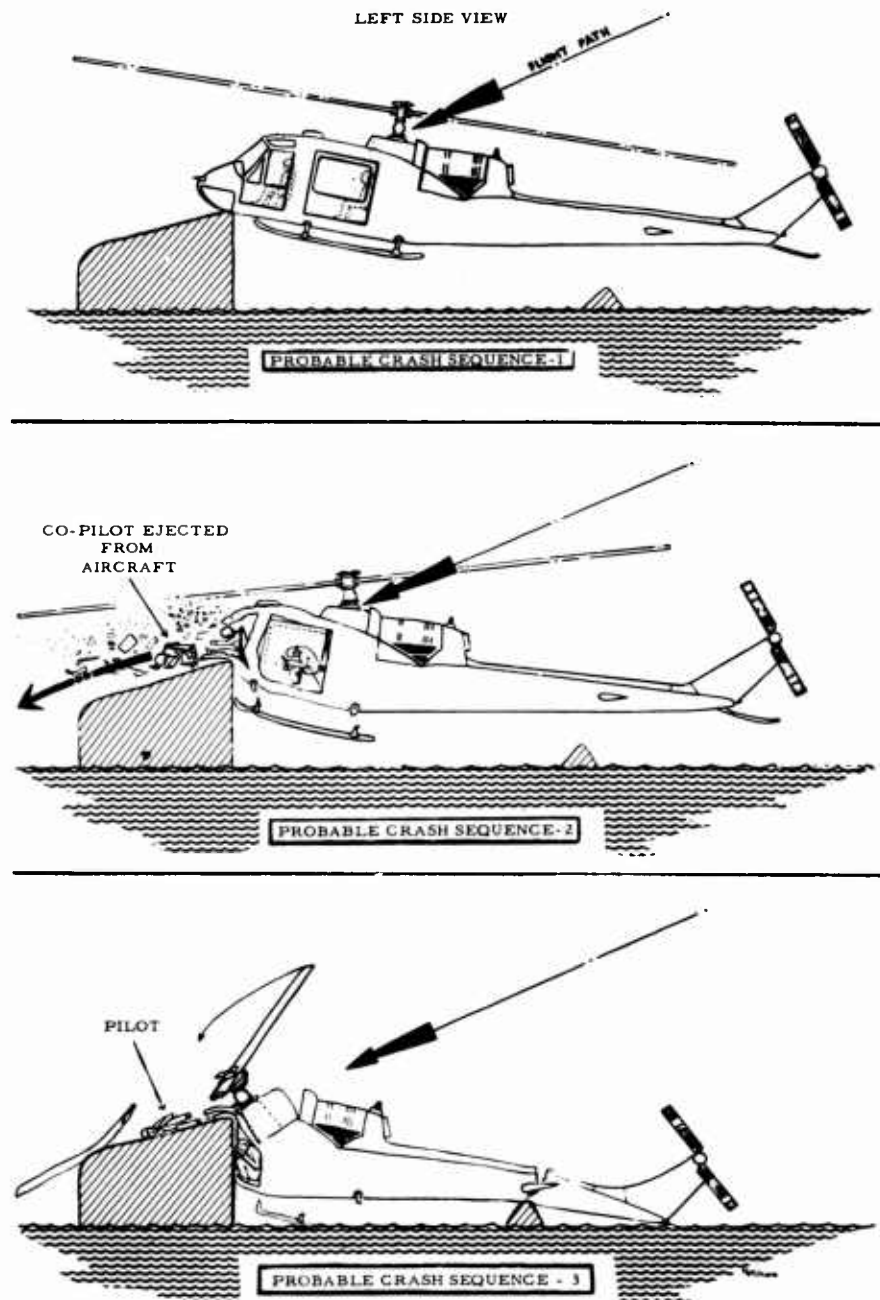


Figure 5. HU-1A Helicopter Probable Crash Sequence, Fort Carson, Colorado.

2. Seat-belt anchorages should provide self-alignment in a manner which prevents amplification of applied loads regardless of the crash force direction.
3. To utilize the protection offered by the APH-5 helmet to the greatest extent, the chin strap must be reinforced.
4. To improve helmet retention, the nape strap of the APH-5 helmet must be made adjustable.

U. S. ARMY NATIONAL GUARD H-23C HELICOPTER ACCIDENT -  
8 DECEMBER 1960, TREC Technical Report 61-68, July 1961

This accident occurred in a flat, unpopulated area while the aircraft was on a night proficiency flight with only the pilot on board. Low-level runs were being conducted with position and landing lights on.

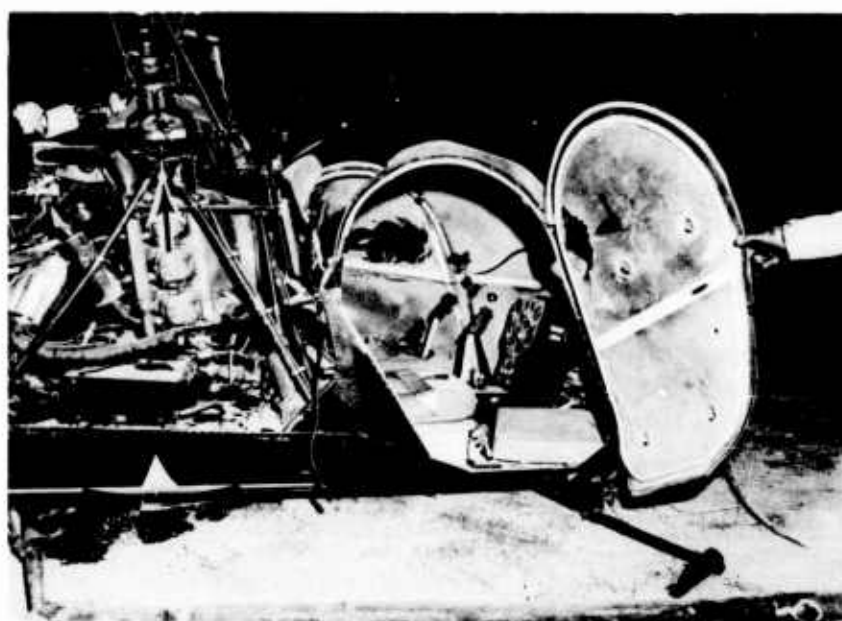


Figure 6. H-23C Helicopter Accident, Phoenix, Arizona.

## WORK ITEM 1

During one of these runs, the aircraft struck the ground slightly nose down in a gentle left turn. The left skid hit first, followed by the left-front underside of the cockpit floor. At this point the rotors appear to have flexed down into the tailboom, shattering the blades and cutting the tailboom into two main sections. While the helicopter was extensively damaged in this accident, the occupiable area remained relatively intact. The pilot was thrown clear when the safety belt latch opened up and no injuries were sustained.

Investigation revealed several features of special significance to crash injury.

1. The safety belt, opening as it did, was found to be a model that can be closed without being in a fully locked position. A latch with positive locking action is indicated as a corrective measure.
2. The safety belt was found to be aligned in such a manner that the belt crossed the upper legs rather than at a 45-degree angle across the pelvic region. This could result in serious spinal injury as the result of flexing generally found in this type of accident. Realignment is recommended.
3. There was no shoulder harness in this aircraft. Experience proves that shoulder harness is an important element in a safe restraint system, particularly for helicopters which tend to roll over on the side. Shoulder harness should be installed for all three seats.
4. Engine mounts failed and the forward displacement of the engine almost impinged upon the occupiable area. Consideration to an improved engine restraint system is suggested.

### UNITED AIRLINES DC-8 ACCIDENT - Denver, Colorado, 11 July 1961

The aircraft involved in this accident crashed on the Denver Municipal Airport while in the process of a landing. There were 115 passengers aboard and a crew of 7. The accident resulted in 18 fatalities.

When approaching Denver, the pilot had informed the passengers of a hydraulic malfunction, but for some reason this briefing was interrupted. The approach and landing were considered normal by passengers and ground witnesses, but during the roll-out the aircraft swerved toward the right and then left the runway. The aircraft sheared the gear on the abutment of a taxi strip under construction and hit a pickup truck which was parked there. A fire started in the left wing, and the aircraft was destroyed.

The evacuation of the passengers was orderly and no panic developed. However, the main exit in the rear of the aircraft was jammed due to the deformation of the floor where the pickup truck was hit by the aircraft and crushed underneath the tail. This probably caused several passengers in the rear of the aircraft to use the forward emergency exits and the rear service door. Many passengers in the forward part of the tourist section used the forward exits and emergency exits over the wing. It is quite possible that many of the nonsurviving passengers, most of whom were sitting in the center part of the tourist section, were trapped between these two crowds, since there are no window exits in this section. Post-mortem investigation indicated that the persons who died in this section became incapacitated by smoke inhalation (carbon monoxide) and asphyxiation before they were exposed to the fire. Thermal injuries sustained by the survivors were most likely incurred during the progress of evacuation and not in the aircraft, while other injuries such as leg fractures also were sustained during the evacuation.

The investigation of the accident was conducted by the CAB. Mr. H. F. Roegner, Chief of the Accident Investigation Branch of AvCIR, was assigned to the Fire Fighting and Rescue Group of the CAB and Mr. G. M. Bruggink and Captain Daniel J. Schneider served on the Witness Group. Complete factual information has not yet been obtained, but future analysis of this accident will be combined with other similar accidents involving postcrash fire and evacuation problems and will be incorporated in a report concerning Postcrash Evacuation in Air Transport Accidents.

CRASH SAFETY DESIGN CRITERIA

AvCIR continues to gather and review specifications, technical standard orders, and related material from military and civilian sources, and from foreign sources as well. Some of the individual studies which are presently being conducted such as "Postcrash Evacuation in Aircraft Accidents" and completed reports such as "Impact Survival in Air Transport Accidents" will form portions of an illustrated manual entitled "Crash Safety Design Criteria". This manual is being developed to illustrate desirable and undesirable crash safety designs. Major subdivisions will deal with: (1) Crash-worthiness, (2) Restraint Systems (Occupant and Equipment), (3) Occupant Environment, (4) Crash Force Energy Absorption, and (5) Postcrash Factors.

Publication of "Design for Safety" memos has been initiated. Each memo will cover a specific deficiency found in an investigation or analysis of an aircraft accident. This deficiency will be illustrated and briefly described for the benefit of aircraft designers. Both military and civilian deficiencies will be included. These publications are to be distributed on a regular basis. A typical memo is shown on the following page.



## WORK ITEM 2

### OCCUPANT RESTRAINT

Improper Harness Tie-down Contributed to Fatal Injury

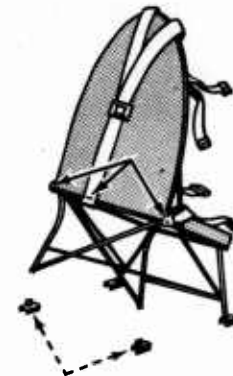


#### CONCEPT

If fuselage structure or a section thereof remains reasonably intact in an aircraft accident, the occupants of these sections should survive. Experience indicates that inadequate occupant restraint is a main cause of unnecessary injury and death.

#### The SITUATION

A light personal plane, converted for agricultural use, stalled out during a turn and struck the ground at an estimated speed of 60 mph and a 30 degree angle of impact. The pilot suffered a depressed skull fracture (fatal) when his head struck the V-braces in front of him. This pilot was wearing a hard hat, a seat belt, and a specially installed shoulder harness. The cockpit area remained relatively intact and the impact conditions can, therefore, be considered survivable.



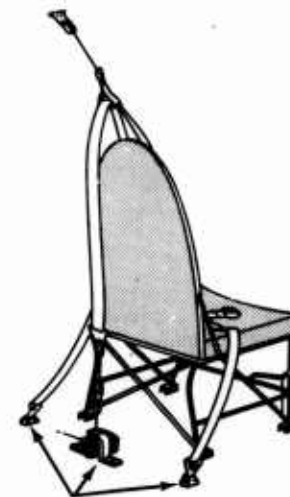
Harness and belt anchored to seat (solid arrows) led to seat tie-down failure (dotted arrows).

#### The HAZARD

Seat belt and shoulder harness were anchored to the pilot's seat. Consequently, all inertia loads resulting from the crash deceleration were transmitted to the seat-floor anchorages. The two aft leg bolts failed and the seat hinged forward, allowing the pilot to come into forcible contact with structure ahead.

#### CORRECTIVE ACTION

To reduce the stress on the seat, restraint systems should be anchored to basic aircraft structure. If this is not practicable, the seat structure itself and its anchorages should be designed to withstand the ultimate dynamic loads compatible with survivable impact conditions.



Recommended method for anchoring restraint system.

AVIATION CRASH INJURY RESEARCH  
2871 SKY HARBOR BLVD. PHOENIX, ARIZONA

A DIVISION OF

FLIGHT SAFETY FOUNDATION, INC.

FSF

AvCIR DFSM NO. 61-1

Figure 7. Flight Safety Foundation, Inc. Design Safety Memo.

MILITARY SPECIFICATIONS AND DESIGN EVALUATIONS

Accident investigations and full-scale dynamic testing of aircraft have brought to light several design details contained in specifications concerning troop seats, litters, and crew seats which have special significance to crash injury and which could be improved by redesign or other change. Specific design details, referenced later, definitely contribute to component failure and, in turn, to occupant injury.

The Military Specifications reviewed in connection with this problem include:

1. MIL-S-27174 (USAF) 8 April 1960 - "Seat, Troop, Variable Seating Width";
2. MIL-S-5705 (USAF) 14 December 1954 - "Structural Criteria, Piloted Airplanes" (Including Crew, Passenger, and Troop Seats and Litter Installation);
3. MIL-S-5804B (ASG) 24 September 1957 - "Seat, Troop, Wall-Style, Cargo Aircraft";
4. MIL-A-8865, relating to litter installations;
5. MIL-A-8867, relating to crew seats; and
6. Other specifications relating to seat belt and shoulder harness installations. (See Work Item 5, Crash Safety Equipment and Procedures.)

Attention also has been given to design evaluations upon the request of the Contracting Officer, namely:

1. U. S. Army HU-1B helicopter; and
2. Type Specification for Light Observation Helicopter (Army) 10 October 1960.

### WORK ITEM 3

#### MILITARY SPECIFICATIONS

##### Troop Seats

Accident investigations continue to point up serious deficiencies in the applicable specifications, deficiencies that definitely contribute to troop seat failures and, in turn, to occupant injury (References 1, 5, 6, 9, 10, and 11). Typical examples are shown in Figures 8 and 9.



Figure 8. Typical Troop Seat Failure.

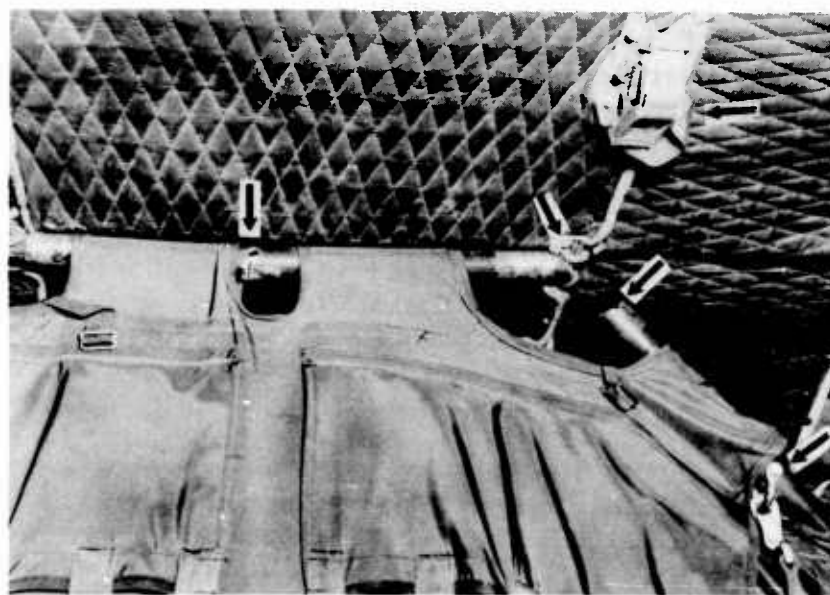


Figure 9. Typical Troop Seat Failure.

During this period, an evaluation was made of certain troop seat specifications. A report on this evaluation is presently being prepared. The purpose of this study was to evaluate certain criteria set forth in the applicable troop seat specifications relative to providing adequate occupant protection during survivable crash force decelerations.

The study includes an evaluation of the criteria set forth in the specifications and points out the deficiencies which exist in the specifications based upon actual aircraft accident experience. The study also presents the findings and results of the experimental research program which are applicable to the troop seat problem.

Additional data, experience, and information were gained in the initial H-25 drop test conducted in October 1960, relative to the existing troop seat deficiencies (References 9 and 10). Based on these data and experience, specifications for an experimental troop seat were established by AvCIR. The details of this seat and the tests to which it was subjected are discussed under Work Item 9.

The results of the tests conducted indicated favorable performance for the new experimental seat. These results are also included in the

### WORK ITEM 3

evaluation of the troop seat specifications.

From accident investigations and analysis, it has been concluded that: (1) the ultimate load-carrying capabilities of aircraft troop seats as dictated by Military Specifications MIL-S-5705, MIL-S-5804B, and MIL-S-27174 are grossly inadequate; (2) the type of construction currently used in aircraft troop seats is in itself an injury-producing factor in aircraft crashes; (3) dynamic testing of aircraft components is a necessary part of functional testing in establishing criteria for Military Specification; and (4) the experimental troop seat design recently designed and tested offers significant improvements over existing troop seat design and capabilities.

#### Litter Installations

This specification evaluation was to have benefitted from the inclusion of a litter installation in the HUP-2 helicopter that was subjected to a full-scale crash test (June 1961). It was found, however, that U. S. Army litters, as used in the H-25, could not be installed in the Navy HUP-2, without extensive modification. Consequently, accurate testing of a U. S. Army litter installation under dynamic crash conditions had to be deferred. This will be incorporated into future crash tests when proper test vehicles become available.

In the meantime, efforts were made to obtain case histories and statistical data relating to aircraft accidents involving litters. . . . Inquiries have been made to the U. S. Naval Aviation Safety Center, Norfolk, Virginia, to the Directorate of Flight and Missile Safety Research, Norton Air Force Base, San Bernardino, California, and to the U. S. Army Board for Aviation Accident Research, Fort Rucker, Alabama. Personal contacts also were made. Results to date have been very sketchy and quite disappointing. Investigation will be continued at Scott Air Force Base, Illinois, and at other possible sources of data.

Interchange of information also is being maintained with various aircraft manufacturers as to their installations in future U. S. Army aircraft (References 2, 3, 4, 8).

#### Crew Seats

Failure of crew seats in accidents considered to be survivable are common (Reference 1, 5, and 6). This is judged to be due to the

inadequacy of the specification and the resultant design, to the anchorage of the seat belt and, at times, to the anchorage of shoulder harness to the seat rather than to basic structure. These features overload the seat and create forces under nominal crash conditions beyond the design limits. This was clearly demonstrated in the H-25 Drop Test, 22 October 1960 (References 9 and 10).

Subsequently, two experiments have been conducted utilizing full-scale crash tests with true dynamic characteristics. In a full-scale drop test of an HUP-2 helicopter on 14 June 1961, the standard crew seat was used, but the seat belt and shoulder harness were attached to basic structure. Collapse of the crew seat legs under these improved conditions further indicates the inadequacy of the design specification. Similar experience, to be reported in greater detail separately, was obtained in still another full-scale drop test on 9 August 1961.

A second experiment relating to the crew seat problem was conducted in the drop test of 9 August 1961. This was the construction of a crew seat frame and the utilization of paper honeycomb (5 layers) as a replacement for the seat pan. A dummy, comparable to that in the pilot's seat, was placed in this improvised seating arrangement with seat belt and shoulder harness anchored to basic structure. Collapsing of the honeycomb occurred as predicted (see Figures 10, 11, and 12), and the vertical accelerations measured in the pelvic region were reduced substantially, probably from nonsurvivable to survivable limits; whereas the peak accelerations on the pilot in the standard seat reached 80-90G, the peak accelerations in the honeycomb seat reached only 30-35G, a 62 percent reduction.

Further experiments of this kind with similarly modified design are planned in an attempt to obtain data and design characteristics that will permit positive recommendations of practical and effective changes in crew seat specifications.

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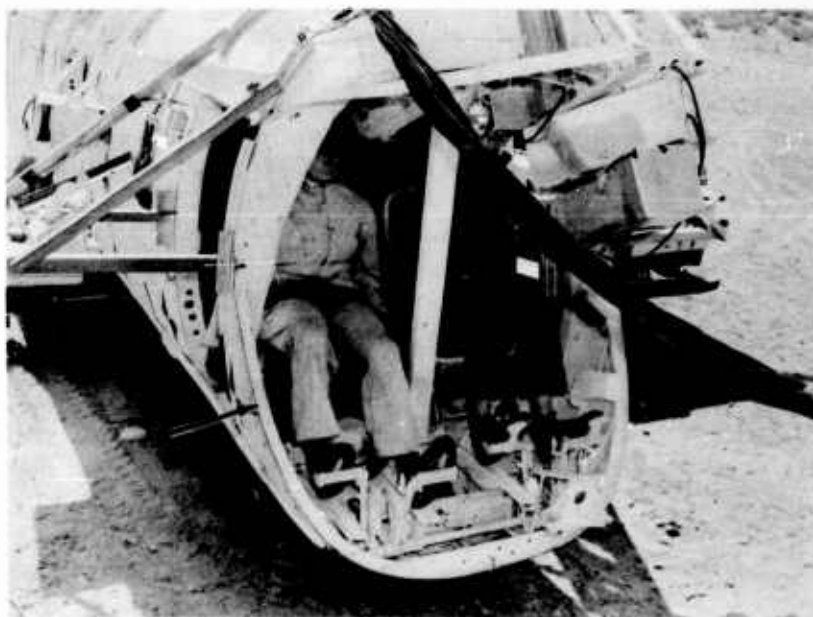


Figure 10. Honeycomb Seat Pan Installation in T-4.

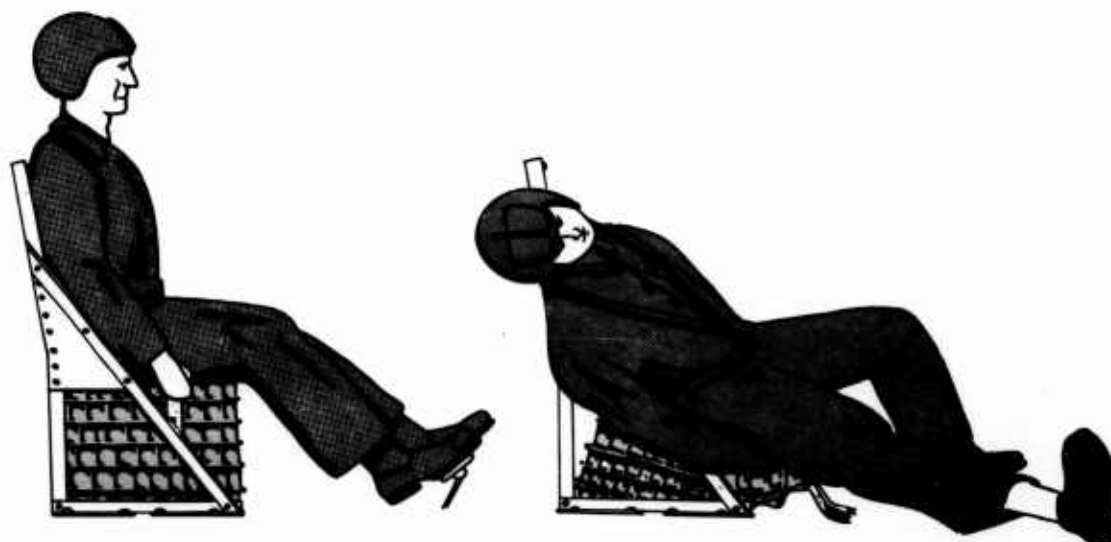


Figure 11. Collapse Sketch of Honeycomb Seat Pan in T-4.



Figure 12. Collapse of Honeycomb Seat Pan in T-4.

#### DESIGN EVALUATIONS

##### U. S. Army HU-1B Helicopter

Under USATRECOM Contract DA-44-177-TC-624, a number of HU-1A accidents had been investigated; also, one crash injury evaluation had been conducted. The findings were published as a "Summary Evaluation of U. S. Army HU-1A Bell Iroquois Helicopter", December 1960 (Reference 7).

In addition, a separate crash injury evaluation had been made on the U. S. Army YHU-1D Bell Iroquois helicopter mockup (Reference 8). Since these evaluations, combined with earlier studies of the HU-1A, had brought out most of the favorable as well as the unfavorable features to be found in the HU-1B, only a Memorandum Report dealing largely with the features peculiar to the HU-1B was issued. The Memorandum Report pointed out that the HU-1B incorporates many desirable features which generally help prevent injuries in the event of an accident. These features are: (1) the skid-type landing gear incorporates energy absorption capabilities; (2) adequate emergency



### WORK ITEM 3

exits are available; (3) the fuel tanks are ideally located in the sides of the fuselage; (4) the "rate of extension" inertia reel utilized on the crew seats will automatically lock when a force of 2 to 3G is imposed from any direction; (5) the troop seat safety belts are anchored to primary structure and cross the hip area at the desired 45-degree angle; and (6) the instrument panel is mounted well forward of the crew members.

The Memorandum Report, however, also pointed out that certain design characteristics may contribute to injuries in the event of an accident, namely:

1. Inadequate structural integrity of the roof side vertical support members, noted initially in the evaluation of the HU-1A (Reference 7) and later corrected in production models of the HU-1B;
2. A sharp lower edge on the instrument panel which can cause fractures of the lower extremities in an abrupt deceleration;
3. Seat belt, shoulder harness, and inertia reel attached to the seats; a method of attachment which can render the restraint system ineffective in the event of seat tiedown failure;
4. Excessive width of the shoulder harness guide permits sufficient lateral movement of the occupant to strike rigid structure within his environment; and
5. The Military Specifications for troop seat installation, litter installation, and litter patient restraint system are incompatible with survivable crash forces.

#### Type Specification for Light Observation Helicopter (Army), 10 October 1960

FSF was requested to review and comment upon this specification from a crash injury point of view. This was completed and a Memorandum Report, dated April 5, 1961, was submitted. Considerable satisfaction was found with the crash load factors being specified. The changes suggested are listed in summary form below:

### WORK ITEM 3

1. Under the section "Crash Landing" which specified ultimate strength for seat installations and attachments of engines and other items, accelerations were expressed only in terms of G units; therefore, dynamic test conditions were suggested including reference to "rate of onset" and "duration";
2. There should be a deviation from MIL-S-7832 to provide for anchorage of seat belts and shoulder harness to basic structure; and
3. Preference indicated for an inertia reel with electromagnetic locking should be deleted.

Additional comments relating to Military Specifications and Design Evaluations will be found under several other Work Items, particularly Number 10 dealing with full-scale crash testing of aircraft.

SPECIAL EQUIPMENT FOR DYNAMIC CRASH TESTS

Since full-scale crash testing of aircraft does not satisfy the need for routine, continuous dynamic testing of the characteristics of many different aircraft and their components, a need for special equipment - a dynamic testing device - is indicated. However, the feasibility, or availability, of such a device needed to be investigated especially as it applies to true simulation of aircraft accidents with forces being experienced in three planes and with varying rates of onset and time phases.

The first step in the investigation was to examine the capabilities of existing dynamic testing devices such as rocket sleds, pendulum swing devices, drop towers, centrifuges, and acceleration systems installed at various locations in this country and abroad. As a result of this initial investigation, none of the devices or facilities in existence were judged to be capable of producing the desired accelerations or forces in three planes simultaneously with independent control of the accelerations or forces in each plane. It was concluded, therefore, that a comprehensive study would be required to determine whether it was feasible to develop a device that would adequately fulfill the test requirements. This resulted in the preparation of a specification that defined the dynamic testing conditions which the device should be required to meet.

The conditions set forth in the specification were based on results from the fixed-wing crash test program conducted by NACA in Cleveland, from the rotary-wing crash test program being conducted by FSF for USATRECOM, and from accident experience. Some of these conditions called for a device which would, insofar as practicable, have the capability of producing accelerations in at least two, but preferably three, coordinated directions. The device would also have provisions for varying the magnitude, time duration, pulse shape, and phase relation of the selected acceleration components simultaneously and independently through a range of values. The maximum acceleration to speed or deceleration from speed for systems in which the main pulses are the acceleration phases was set forth at 4G. The peak acceleration for rectangular, triangular, and sinusoidal pulses were to be adjustable prior to test throughout the range from 5G to 100G for all speeds to 90 miles per hour. Maximum size of the test specimen was indicated to be on the order of 8 feet x 8 feet x 8 feet with a maximum specimen weight of approximately 4,000 pounds.

#### WORK ITEM 4

The specification was submitted to more than twenty engineering or research organizations with a request for proposals to conduct the feasibility study; eight proposals were received. Decision as to the award will be made later and completion of the study is planned for March 1962.

CRASH SAFETY EQUIPMENT AND PROCEDURES

During the full-scale crash test described under Work Item 10, various components such as seat belts, shoulder harnesses, crash helmets, and energy-absorbing materials were tested under dynamic conditions comparable to those experienced in actual accidents on record. This testing provided reliable and valuable performance data relative to crash forces which in the past had been largely speculative.

EVALUATION OF APH-5 CRASH HELMET

One study was an evaluation of the Army APH-5 crash helmet, including the accumulation and analysis of accident experience in which this crash helmet played a part. The analysis, however, provided only general information which was not adequate to prepare or suggest specific recommendations with regard to improvement of the crash helmet design. It, therefore, was decided that newer experimental crash helmets, currently under development, would be installed on the dummies in the scheduled drop tests under the experimental research program. New experimental helmets for this purpose were provided by the Quartermaster Corps upon request of USATRECOM.

During the drop of the HUP-2 helicopter in June 1961, one of the new APH-5 crash helmets was mounted on the pilot dummy. During the crash, the fuselage frame located in the immediate vicinity of the pilot and copilot crew seats collapsed sufficiently to impact on the crash helmet of the pilot dummy. The impact was sufficient to snap the neck of the dummy, and the crash helmet was extensively damaged during the impact.

Although acceleration readings had been taken in the head of the dummy, it was impossible to determine the extent of the energy absorbed by the crash helmet itself because of the fact that no instrumentation was mounted on the external surface of the helmet. Further, during a crash such as this where the dummy's head moves considerably, some doubt arises as to the validity of data which only can be obtained from external instrumentation.

As a follow-through, Dr. Snively of the Snell Memorial Foundation, Sacramento, California, was asked to duplicate the crash in which the conditions involving the helmet could be simulated. The damaged

## WORK ITEM 5

helmet was sent to him along with the structure which impacted on this helmet and a detailed engineering description of the action which took place during the crash. The U. S. Quartermaster Corps also sent Dr. Snively several new helmets for his use in reproducing the conditions experienced.

Under the closely controlled conditions which are available in the Snell Laboratory, Dr. Snively has reproduced the situation which existed in the crash test and is preparing an analysis of the data. It is anticipated that the data obtained will help determine the amount of energy absorbed by the helmet and provide some indication as to the effectiveness of the helmet from an energy absorption point of view.

### EVALUATION OF SEAT BELT AND SHOULDER HARNESS SPECIFICATIONS AND INSTALLATIONS

One study dealt with the protective limits of aircraft seat-belt protection as discussed in available literature and compared with recent crash injury experience (Reference 14). In this study three cases in which aircraft occupants restrained only by seat belts received serious or fatal decelerative injuries were reviewed. The study indicated some of the types of injuries that may be expected when the tolerable and injurious limits of seat-belt protection are exceeded.

To insure maximum survivability under the most adverse conditions, the strength of a seat-belt restraint system should be based on the threshold between the injurious and fatal limits of seat-belt restraint. Thus, an aircraft seat-belt restraint system with an energy absorption capability of 25G, based on occupant weight of 200 pounds for a duration of at least 0.2 second, may form a realistic compromise between the ideal and the practicable strength of such a system. The study also revealed that full protection of seat-belt restraint can be realized only when the occupant has an unobstructed path for his flailing extremities and upper torso. If this condition does not exist, the protection offered by the seat-belt restraint may not be limited by G factors, but by the injurious aspects of the occupant environment.

A paper covering this study is to be presented at the International Congress of Aviation and Cosmonautical Medicine in Paris in the latter part of September of this year. The report also will be

published by USATRECOM.

Most of the relationships of seat-belt and shoulder-harness installations with crash injury have been voiced in reports of accident investigations (References 1, 5, and 6); in aircraft evaluations (References 3, 4, 7, and 8); in statistical reports (Reference 12); and in the discussion of results from full-scale crash tests (References 9, 10, and 11). In summary, the conclusions generally are as follows:

1. Seat belts and shoulder harness should be fastened to basic structure whenever practical;
2. Shoulder harness should be available for all crew seats;
3. All seat belt installations should permit the belt to cross the pelvic area at an angle of approximately 45 degrees;
4. Shoulder-harness guides should be as narrow as possible to minimize lateral movement; and
5. Not more than one seat belt should be fastened to any single attachment point.

STATISTICAL AND CLINICAL ANALYSIS OF ACCIDENT DATA

Substantial support for conclusions and recommendations with respect to crash safety design is developed through statistical and clinical analysis of mass aircraft accident data, both engineering and medical. These data are obtained from routine reporting of accidents by military and civilian agencies. Detailed reports on special AvCIR accident and medical forms are received from offices of the Federal Aviation Agency, Civil Aeronautics Board, state aviation agencies, state police groups, and the U. S. Army.

During the past year, a number of statistical and clinical studies were conducted dealing with mass accident data as they relate to the production of injuries or fatalities in aircraft accidents where the findings are applicable to almost any aircraft type, military or civilian (References 12, 13, 14, and 16). The ultimate goal toward which this portion of the research activity is directed is, of course, the reduction of fatalities and injuries in aviation accidents through the application of design principles which increase the crashworthiness of aircraft and decrease the crash forces to which occupants may be subjected.

One step in this direction is that of identifying the causes or describing the ways in which the fatalities or injuries are produced. This then leads to an understanding of the complex interplay of forces during the occurrence of the accident event. With such an understanding, design principles and accompanying recommendations can be deduced which, when implemented, may be expected to reduce fatalities and degree of injury.

A further objective must be obtained before such a reasonable understanding can be reached. This is the objective of establishing functional relationships between causes and effects in the accident situation. This objective also yields the tool whereby effectiveness of changes in design or other modifications of aircraft safety features can be evaluated. The problems of defining suitable accident variables to describe the initial conditions, the resultant outcomes, and appropriate scales of measurement for these variables are a part of this objective.

To achieve these objectives, a more complete understanding of the interrelationships or correlations between three main variables - impact configuration, damage, and injury to the occupant - needed



## WORK ITEM 6

to be developed. Each of these variables must be objectively measured if reliable correlations between the variables are to be obtained. For any particular scale, it is always helpful to have a sufficient number of intervals or categories of response to permit adequate definition of the variables that are being measured; i. e., if degree of injury is to be measured, saying that the person is dead or alive is not enough. It is necessary to know how badly he is injured - even though he is fatally injured. Was there one primary cause of death or several causes of death? Similarly, with the damage scales, it is necessary to know whether the plane was damaged slightly, whether there was considerable structural collapse, excessive structural collapse and disintegration, or complete disintegration. In other words, the more steps in the rating scale, the more information can be obtained and used in the statistical analysis. This raises an important question, however, as to how many scales or intervals can be discriminated by an investigator.

In theory, complete knowledge about the variables at impact, coupled with knowledge of the engineering characteristics of the mechanical structures, including the human occupant through which these impact forces are transmitted, would enable perfect prediction of all the damage effects (injury to the occupant can be considered as damage to the human structure). Based upon the foregoing, a logical question was raised - "To what extent can we predict damage to the human structure from the knowledge of a single accident variable?"

### PREDICTION OF DEGREE OF INJURY FROM IMPACT AND DAMAGE VARIABLES IN LIGHTPLANE ACCIDENTS

A statistical study was initiated, therefore, involving 913 accident cases that had been collected from 1942 to 1952 (Reference 13). The results of the study indicated that really none of the primary impact variables gave a very high prediction of injury severity and that these impact variables by themselves showed low intercorrelations with each other; that is, one was not related very highly with another. However, since each of the variables did correlate somewhat with the criterion, "injury severity", it appeared that different aspects of the overall accident picture were measured by these different primary impact variables. From this it seemed logical to consider a composite impact severity measure based on velocity at impact, the angle of impact, and stopping distance. The results here revealed that even this composite measure was not a good predictor

of injury severity. It was apparent that these gross impact variables, even in combination, failed to describe adequately the initial circumstances surrounding the accident event.

This study, therefore, raised several questions. One question was "How reliable are the estimates of the impact variables as obtained from field investigators' reports?" It is possible that the unreliability of such estimates may make it difficult to go beyond a simple descriptive effort. Another question was the possibility that certain aspects of the crash event were not covered by the impact variables considered in the study. The roll and yaw attitude of the aircraft, seated position of the occupants, terrain features, and the effects of seat and restraint system failures were not considered. Thus, the study pointed the way to further studies involving these factors.

#### FACTOR ANALYSIS OF LIGHTPLANE ACCIDENT IMPACT AND DAMAGE VARIABLES

The next study (Reference 14) was a factor analysis of lightplane accident impact and damage variables. The factor analysis was made with an IBM 650 computer by utilizing accident statistics punched on IBM cards. The purpose of this analysis was to determine the meaningful variables in the crash picture that should be measured. The variables fed into the computer consisted of pitch, roll, terrain at impact, impact velocity, impact angle, stopping distance, gouge depth, damage to various parts of the aircraft, including cockpit area, seat, the occupant's particular environment, instrument panel, and damage to the individual and the head structure.

Four factors related to the description of the conditions at impact were revealed - impact velocity, terrain conditions at impact, roll, and pitch. As to the consequences of impact, four factors also were revealed; these were tiedown effectiveness, two damage factors (one to the nonoccupied area and one to the occupied area), and injury severity.

This analysis confirmed the conceptual framework through which accident variables have been defined. It also was noticed that the relationships between aircraft structural damage and injury to the occupant increased as a function of proximity; i.e., relationship between damage to the aircraft's nose and injury severity was not as great as that between the front of the cockpit and injury severity and, in turn, this was not as high a relationship as that between the

## WORK ITEM 6

occupant environment damage and injury severity.

### INJURY SEVERITY AS RELATED TO SEAT TIEDOWN AND BELT FAILURE IN LIGHTPLANE ACCIDENTS

A third study (Reference 12) dealt with the role of tiedown effectiveness in which 1,025 occupants of lightplanes were involved in ground-object collisions or in spin-stall crashes. The findings may be summarized generally as follows:

1. Critical injuries to the head and the upper torso occurred even though there was adequate seat belt restraint;
2. Lumbar spine injuries frequently stood out as exceptions to general trends; and
3. Lumbar spine injuries were fewer when seat belts were not worn; they decreased with impact angles greater than 45 degrees, but increased as a function of stopping distance for occupants whose belts and seats both held.

Accident experience has shown that lumbar spine fractures are most commonly associated with impact conditions in which the resultant forces are principally vertical and are directed upward through the seat. Thus, such fractures are seen to occur most frequently in low-angle crashes which, in turn, are characterized by long stopping distances. Adequate restraint, then, can be seen to contribute to this form of injury insofar as it acts as a counterforce against which vertical forces are applied. (The more rigidly an occupant is restrained in the seat as the aircraft bounces over a relatively long distance, the more the spine is subjected to damage.) With the additional increased use of shoulder harnesses, lumbar spine fractures may be expected to become the most frequent type of major nonfatal injury in lightplane accidents, as U. S. Air Force experience has indicated.

In the AvCIR study, belt failure was found to occur much more frequently than seat failure, yet injury severity was greater when seats failed than when belts failed. It was felt that this was due to the fact that seat belts absorb decelerative energy before failing, thereby reducing the force with which the occupant contacts forward structures, whereas when a seat fails, it is the human structure alone which must absorb decelerative energy, and seat weight is

added to body weight. In general, the findings indicated that factors other than tiedown failure were responsible for the major portion of injury severity, although to be sure, tiedown failure did contribute significantly to injury.

#### LIMITS OF SEAT-BELT PROTECTION DURING CRASH DECELERATIONS

Another study (Reference 15), closely related to that discussed above, was discussed under Work Item 5. This was a clinical, nonstatistical analysis of the limits of seat-belt protection during crash decelerations wherein the protective limits of aircraft seat-belt protection were compared with recent crash injury experience. The study pointed up some of the injuries which may be expected when the tolerable and injurious limits of seat-belt protection are exceeded. It was found that full protection of seat-belt restraint can be realized only when the occupant has an unobstructed path for his flailing extremities and upper torso. If this condition does not exist, the protection offered by seat-belt restraint may not be limited by G factors but by the injurious aspects of the occupant's environment. From this it might be concluded that an aircraft seat-belt restraint system with an energy-absorbing capability of 25G for a duration of at least .2 second may be a realistic compromise between the ideal and practicable dynamic strength of such a system provided there can be protection from the surrounding environment.

#### RELATIONSHIP BETWEEN IMPACT VARIABLES AND INJURIES SUSTAINED IN LIGHTPLANE ACCIDENTS

A fourth statistical study (Reference 16) considered both degree of injury and area of injury as they were related to impact conditions for a group of occupants whose tiedown did not fail. The study involved 248 occupants sitting, in turn, in the front left seat (normally the pilot) or the front seat in tandem seat aircraft. Structural collapse in these 248 crashes was generally not extensive; yet, approximately one out of every four occupants was fatally injured. As with the tiedown study (Reference 12), mean degree of injury and fatality rate were directly related to impact velocity and to angle of impact but inversely related to stopping distance. Incidence of injury to all areas of the body except the lower torso and thoracic and lumbar spine areas followed the same trends. Again, lumbar spine injuries occurred more frequently in low-angle, long-deceleration crashes.

## WORK ITEM 6

From this study it was concluded that crucial injuries - those to the skull and its contents, the cervical spine, and the upper torso - largely resulted from flailing of the body against injury-producing structure within the occupant's environment. Belt restraint was seen to play only a moderate role in reducing injury severity. The need for shoulder-harness installations and incorporation of energy absorption principles in cockpit design was emphasized.

It should be noted that the results for three of the above studies (References 12, 13, and 16) were obtained on data collected during the period 1942-1952. Such data, therefore, can be expected to reflect (1) a greater variability in structural design to be found in lightplanes of this era, and (2) the smaller body of knowledge of safety practices then available. Follow-up studies, based on data collected between 1953 and 1960, are currently in progress in order to determine the generality of the earlier findings.

From all of these studies, it was recognized that the findings were not nearly as clear-cut as they might have been had more appropriate and more accurate measures of impact severity and occupiable-area damage severity been available. It seemed, therefore, a logical step to focus attention on the development of a better report form and of better scaling and coding practices for IBM data processing.

This more refined statistical analysis will encompass several different approaches including the following:

1. Determine the extent to which postcrash observation of damaged aircraft can be used to describe the events that occurred at the time of the accident. This aim fulfills a need for improved methods of investigation that lead to quantification along the dimensions of similarity and difference in crash configurations so that types of accidents can be functionally defined.
2. Establish relationships between measures of damage to the aircraft and measures of injury to the occupant. Kind and degree of injury vary as a function of the pattern of forces generated in different types of crashes. The relationships sought by this aim will provide the empirical basis for constructing a "theory of the crash" -- a predictive model in the form of a computer program that will (1) generate the values of the crash forces that occur at the time of the

accident given the damage and injury values or (2) generate the damage and injury consequences given the values of the crash forces for different types of accidents.

3. Relate findings obtained above to specific aircraft makes and models so that specific injury-producing factors in aircraft design can be identified and information about these factors can be communicated to the appropriate audiences. The several direct outcomes of this research include (1) a more precise understanding of the interactions among accident variables and causes of injury, (2) better methods of investigating aircraft accidents including attention to the training and experience requirements for accident investigators, and (3) a data collection and analysis system that will permit evaluation of trends in frequency and severity of lightplane crashes over the years. The latter implies the development of a continuing program of research into the requirements for design and use of aircraft that will increase survivability in the event of a crash.

LIAISON WITH GROUPS AND AGENCIES

During the reporting period, members of this organization participated in several conferences, meetings, symposia, and seminars related to the Aviation Crash Injury field. The exchange of information at these meetings was found to be of real value to the objectives of the program. Three of the more pertinent of these meetings, or symposia, are summarized below.

Symposium of Biomechanics of Body Restraint and Head Injury  
Conducted at the Naval Air Materiel Center, Philadelphia,  
Pennsylvania, June 14-15, 1961:

The purpose of this symposium was to increase the quality and effectiveness of research, by all associated agencies, in the aircraft occupant protection field. The program was divided into five sections: Accident Investigation, Experimental Techniques, Head Injury, Acceleration Tolerance, and Restraint Systems. Extensive material was presented in each of these fields making this an extremely worthwhile and fruitful meeting.

An excellent presentation of the history, development, and future plans of the USATRECOM overall aviation safety program emphasized the significance of dynamic crash testing of full-scale aircraft and crash and postcrash fire prevention.

Of additional interest was the presentation on Intra-Cranial Pressure and Acceleration Accompanying Head Impacts. This dealt with the field of acceleration and head and neck injuries which relate to work in the crash-helmet evaluation fields.

Aerospace Medical Panel of the Advisory Group for Aeronautical  
Research and Development (AGARD), Conducted at Oslo, Norway,  
24-29 July 1961:

This symposium consisted of papers presented to the Avionics, Fluid Dynamics, and Aerospace Medical panels, and the meeting of the 11th General Assembly of AGARD. Observations were made only at the Aerospace Medical panel meeting and the General Assembly meeting due to the vastness of the material in all of the panel meetings.

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Many aspects of Aviation Medicine were discussed concerning flight both in our atmosphere and in space, including such problems as hyperventilation, hypoxia, weightlessness, and fatigue. In the field of Army aviation the presentation on fatigue in low-flying VTOL aircraft and the occurrence of flicker vertigo in helicopters were most informative and important with respect to accident prevention.

Twelfth Meeting of the Emergency Egress Committee (U. S. Navy)  
at Lockheed Aircraft Corporation, Burbank, California, 16-17 August  
1961:

The Emergency Egress Committee is made up of representatives from various organizations in the aircraft industry and meets for the purpose of exchanging information with regard to developments involving emergency egress from aircraft.

Most of the information presented at the meeting had to do with ejection seats of various types and with progress that had been made in the development of such seats with the emphasis being on ejection from aircraft prior to impact. The AvCIR Division of the Flight Safety Foundation made a presentation dealing with protection of the occupant during crash in rotary-wing type aircraft from which ejections are not feasible. The presentation covered the full-scale crash test experiments being conducted by AvCIR, for the U. S. Army, including the accumulation of data on accelerations and forces experienced by occupants involved in rotary-wing accidents and ways and means by which such accelerations and forces can be reduced to improve the rate of survival in accidents involving rotary-wing aircraft.



TRAINING IN CRASH INJURY INVESTIGATION

The U. S. Army recognizes the urgent need to develop a group of key military personnel with specialized skills for the scientific investigation of aircraft accidents as they affect injury and survival. Only from this can come the more complete and accurate information required by analysts and designers in the determination of causes of injury and, subsequently, in the development of improved designs or procedures.

During the contract period, three training courses of 2-weeks' duration each were held in which forty military students were trained. Of these, eighteen were flight surgeons and aviation medical officers, sixteen were aviation safety officers, and six represented research, development, and procurement activities.

The curriculum of this course is designed to provide personnel with the knowledge necessary to investigate and analyze aircraft accidents relative to: (1) finding specific causes of minor, serious, and fatal injuries sustained in fixed-wing, rotary-wing, and transport-aircraft crashes; (2) determining reasons for survival and nonsurvival; (3) evaluating the effect of crash safety design, both structural and environmental; (4) evaluating the overall crashworthiness of aircraft in relation to impact severity; (5) recommending new engineering design criteria to prevent serious or fatal injuries from occurring in future survivable-type accidents. The value of this program is evidenced by the much higher quality of crash injury reports received by AvCIR from Army field agencies when accident investigations have been handled by those with this training background.

Of the total of 60 hours comprising the course, one-half of the time is devoted to the investigation phases, including 8 hours of field investigation at simulated accident sites and 4 hours of crashworthiness evaluation and analysis of actual aircraft.

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The following table summarizes military attendance:

<u>Dates</u>	<u>Aviation</u>	<u>Military Medical</u>	<u>MSC R&amp;D</u>
5 Dec - 16 Dec 1960	4	3	2
30 Jan - 10 Feb 1961	5	8	--
13 Mar - 24 Mar 1961	<u>7</u>	<u>7</u>	<u>4</u>
Totals:	16	18	6



Figure 13. Typical Group of Military Students and Instructors in Crash Injury Investigators' Course.

## WORK ITEM 8

All instruction is handled by AvCIR staff; however, this customarily is supplemented by specialized, technical presentations by one or two guest lecturers at each course. The following contributed greatly to the success of these courses during this period:

Bernard C. Doyle, Chief, Human Factors Division, Bureau of Flight Safety, Civil Aeronautics Board, Washington, D. C.

I. Irving Pinkel, Chief, Fluid Systems Components Division, Lewis Research Center, NASA, Cleveland, Ohio.

W. Harley Davidson, Captain, USAF (MC), Chief, Aerospace Branch, AFIP, Washington, D. C.

Frank G. Andrews, Head, Civilian Section, Aircraft Accident Prevention and Investigation, Aviation and Missile Safety Division, University of Southern California, Los Angeles, California.

John L. McWhorter, Bureau of Safety, Civil Aeronautics Board, Miami, Florida.

RELATED TASKSREMOTE CONTROL SYSTEM FOR HELICOPTERS

The initial full-scale crash test experiment in October 1960 was conducted for the purpose of measuring accelerations and forces in the structure, seats, dummies, and other components of the aircraft under a simulated crash condition. Another objective of the initial test was to determine problems inherent in experimental dynamic testing for use in the design of subsequent experiments of a more complex nature.

The aircraft used in the test was a nonoperable H-25 helicopter. The method of drop consisted of suspending the aircraft from the boom of a crane at a height of 30 feet and driving the crane down the runway. At a predetermined point the aircraft was automatically released and impacted on the target. The test indicated that this method provided an economical system for obtaining three-dimensional acceleration and force data. Four additional tests were made during this contract period, utilizing this method. The details of these tests are covered under Work Item 10.

It was realized, prior to the conducting of these tests, that certain effects of a crash could not be duplicated by using the crane drop method, these effects being those resulting from the rotating components (rotors, engines, transmissions and shafting) during a crash. It was felt, however, that these effects, when measured in later tests, could be applied to the earlier acceleration and force data if they were found to be significant.

In order to measure these effects on accelerations and forces experienced in a crash, the aircraft must be crashed under conditions involving operation of the engines and rotors. Since this was not possible with the crane drop method, some other crash technique had to be developed, preferably one which permitted crashing the aircraft from actual flight. Such a method would also permit the expansion of test objectives to include the investigation of postcrash fire and crash fire inerting systems.

A study was conducted on possible ways of crashing a helicopter from flight through the use of a remote control system. Previous work on autopilot and remote control systems performed by numerous organizations was studied and evaluated. Upon completion

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of the study a specification was prepared for the development of a simplified remote control system for an H-21 helicopter. This specification will be forwarded to interested prospective contractors with a request for proposals for the development of the system.\*

### DEVELOPMENT AND TEST OF EXPERIMENTAL TROOP SEAT

Accident experience over the years with the troop seats designed in accordance with military specifications has revealed that the specifications and seats are inadequate from a crash safety point of view. Gross failure has been experienced repeatedly, even in accidents where minimal crash forces were involved (References 1, 5, 6, and 7).

Efforts to improve this situation were hindered by the lack of information on accelerations and forces which may be expected in accidents, particularly those involving rotary-wing aircraft. Information on these accelerations and forces was obtained during the H-25 crash test conducted in October 1960. The information indicated that the forces were significantly higher than the load limits to which the seats were designed. It was felt, however, that seats could be designed, using the acceleration and force data obtained in the 1960 drop test as criterion, which would result in a seat capable of withstanding the anticipated forces without gross failure.

Authorization was obtained to purchase four experimental troop seats of a new design for testing in one of the aircraft to be crashed during this contract period. A subcontract was awarded to Hardman Tool and Engineering Company for the design and construction of four experimental seats. The design of these seats was based upon the criterion provided from the results of the 1960 H-25 crash test.

During the H-25 crash test, it was found that extremely high vertical accelerations were experienced in the floor structure of the aircraft. Because of design characteristics, this is a condition which can be expected in most all rotary-wing aircraft when involved in a crash.

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\* As of publication of this report, a subcontract has been awarded to Kaman Aircraft Company for the design, fabrication, and test of a simplified remote control system for the H-21 helicopter. The system is based upon a combination mechanical ILS-radio link control system. This simplified system will be readily adaptable to all rotary-wing and fixed-wing aircraft for any desired full-scale aircraft crash research.

The concept for the experimental seat, therefore, was based on suspending the seat without the use of floor attachments inasmuch as the high vertical accelerations experienced in the floor structure contributed significantly to the failure of seats attached to the floor. The experimental seat was designed to be attached to the roof and side-wall structure of the aircraft. This would eliminate the high vertical accelerations transmitting through the seat structure from the floor and would also utilize the side-wall and roof structure of the aircraft to attenuate forces transmitted to the seat and occupant. In addition, mechanical energy absorption devices were installed in the upper support member of the seat which permitted a 6-inch stroke of the seat pan, providing additional stopping distance for the occupant, thereby reducing the peak accelerations experienced by the occupant. The seat-pan stroking mechanism was designed to lock in the down position to prevent rebound. Sketches of the seat are shown in Figures 14 and 15.

Two of the seats were installed in the HUP-2 helicopter which was crashed in August 1961 (see Work Item 10). One of the seats was mounted at the rear fire wall in the forward-facing position, and the other seat was mounted on the left-hand side wall in a side-facing position. Figure 16 shows one of the seats mounted on the rear fire wall in the forward-facing position with the dummy in place. Figure 17 shows the same seat after the crash. Here it will be noted that the dummy is in relatively the same position occupied prior to the crash and that the seat is reasonably intact in spite of the high accelerations to which it was subjected and the fact that the floor structure broke up badly underneath the seat and impacted against the bottom of the seat.

Although some deformation of the seat structure was experienced, the only significant damage to both seats was ruptured seat pans as shown in Figure 18, a situation which can be readily corrected.

The results of the test indicated favorable performance of the new experimental seats in that there was no gross failure even though the seats experienced vertical accelerations in excess of 65G while simultaneously experiencing longitudinal and lateral accelerations on the order of 45 and 20G, respectively.

The experimental seat design is to be further tested under closely controlled conditions on the vertical drop test device in the Aerospace Medical Laboratory at Wright-Patterson Air Force Base. The purpose of these tests is to optimize the design from the standpoint of the ideal number of energy absorption devices and in the method of support between the upper attachment point and the seat-pan arrangement.

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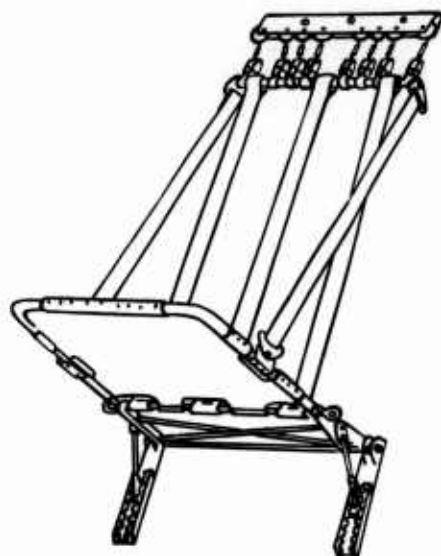


Figure 14. Experimental Troop Seat (Bottom View).

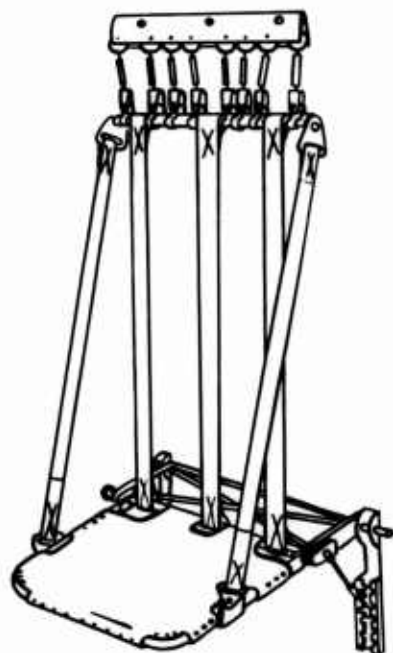


Figure 15. Experimental Troop Seat (Top View).

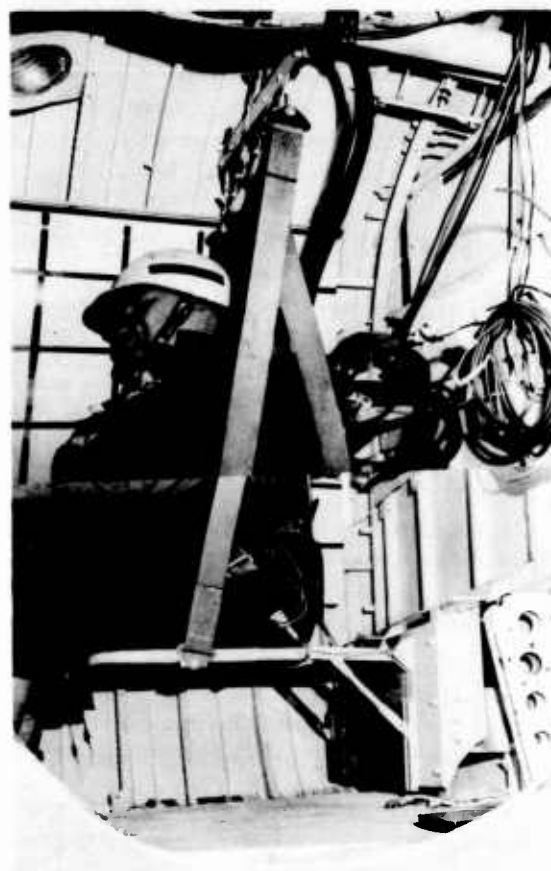


Figure 16. Experimental Troop Seat Prior to Test.

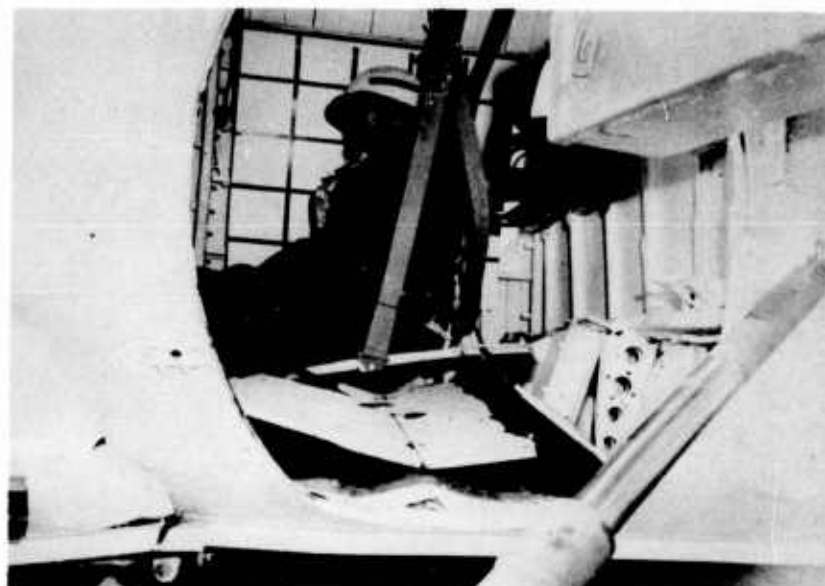


Figure 17. Experimental Troop Seat After Crash Test.

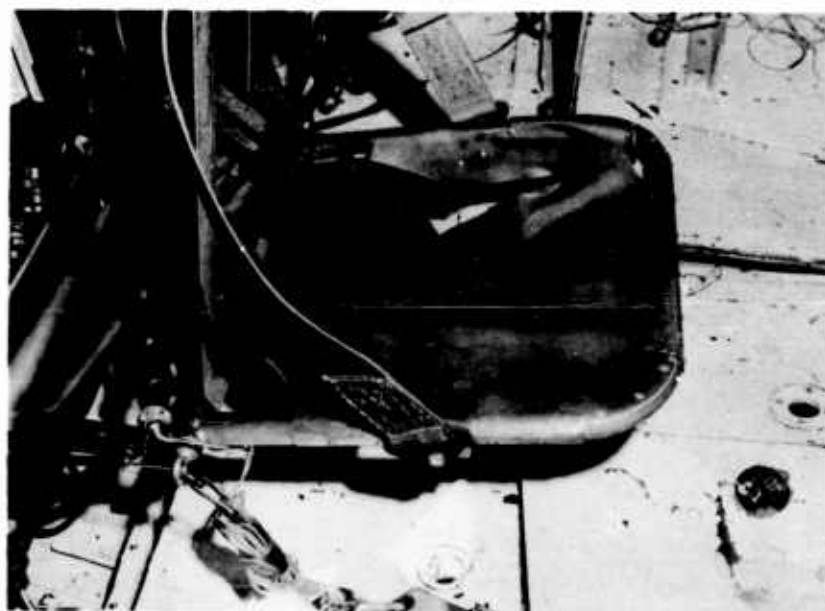


Figure 18. Experimental Troop Seat After Crash Test.



FULL-SCALE CRASH TESTS

As a continuation of the program of dynamic testing of aircraft and their components, inaugurated with the drop of an H-25 helicopter from a moving crane in October 1960 (References 9 and 10), four additional helicopters were crashed using the same technique and comparable configurations. Two were HUP-2 helicopters, the U. S. Navy version of the H-25, and two were H-13 Bell helicopters.

A primary purpose of these additional crash tests was to establish a pattern of repeatability of test results; however, they also permitted a degree of experimentation with a number of design and installation changes indicated as desirable in the initial drop of the H-25. In addition, they permitted some refinement in test techniques.

Since the drop of the H-25 helicopter in October 1960 was identified as FSF Test No. 1, the four tests covered in this report are identified as Tests No. 2 through No. 5, and were conducted on the following dates:

Test No. 2 - HUP-2 - 14 June 1961

Test No. 3 - H-13 - 17 June 1961

Test No. 4 - HUP-2 - 9 August 1961

Test No. 5 - H-13 - 3 August 1961

The Navy Model HUP-2 helicopters used are, for practicable purposes of the tests conducted, identical to the Army H-25 helicopter used in Test No. 1 in October 1960.

The basic purpose of this series of tests was to obtain acceleration and force data from the aircraft structure when subjected to conditions simulating known accident configurations. These data will permit definition of the crash environment. The information when reduced to engineering terms will permit the designer to include crash safety provisions in the design of basic aircraft structure and in the design and development of components such as seats and restraint systems. A better understanding of the crash environment will also be extremely valuable in assessing the effects of injuries in aircraft accidents, particularly with regard to helicopters, VTOL- and STOL-type aircraft.

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To obtain the desired data, acceleration measurements were made in three planes in most of the locations measured. Measurements were made at the floor nearest the point of impact, in the seats, and in the pelvic and/or chest and head regions of the dummies. In the case of the original H-25 test conducted in 1960 and the two HUP-2 tests conducted during the period covered by this report, this group of measurements was made in both the cockpit and cabin sections of the aircraft. Location of the accelerometers at these points permitted the measurement of accelerations near the point of impact where the accelerations are highest and at various distances from the point of impact.

The purpose of selecting these locations was not only to measure the magnitude of the accelerations at the various points but also to show how these accelerations were attenuated between the various locations through failure or destruction of material between the point of impact and the location at which the measurements were taken.

Force transducers were used in the restraint systems, and strain gauges were applied at critical locations such as engine mounts and seat legs. High-speed cameras were mounted in various strategic locations, both on board the aircraft and on the ground, to record on color film all action taking place during the crash. Artificial lighting was used in the HUP-2 helicopters for better photographic coverage.

The same drop method was used for each of the four aircraft. It consisted of suspending the test article from the boom of a crane at a height of approximately 30 feet, and with the boom of the crane pointing toward the rear, the crane was driven down the runway at a speed of approximately 30 miles per hour. At a predetermined point the suspension hook was automatically released, permitting the aircraft to impact on the target. The method of suspending the aircraft is illustrated in Figure 19. All aircraft were dropped with the rotor blades in place but not rotating.

There were some differences in forward speed attained by the crane during the drop runs and in the pitch, roll, and yaw attitudes of the test articles at the time of impact. These differences are indicated in Table 1, and were due to the wind force, wind direction, and temperature at drop time. A preliminary examination of the data obtained indicates that the influence of the above-cited differences on the data obtained was negligible.

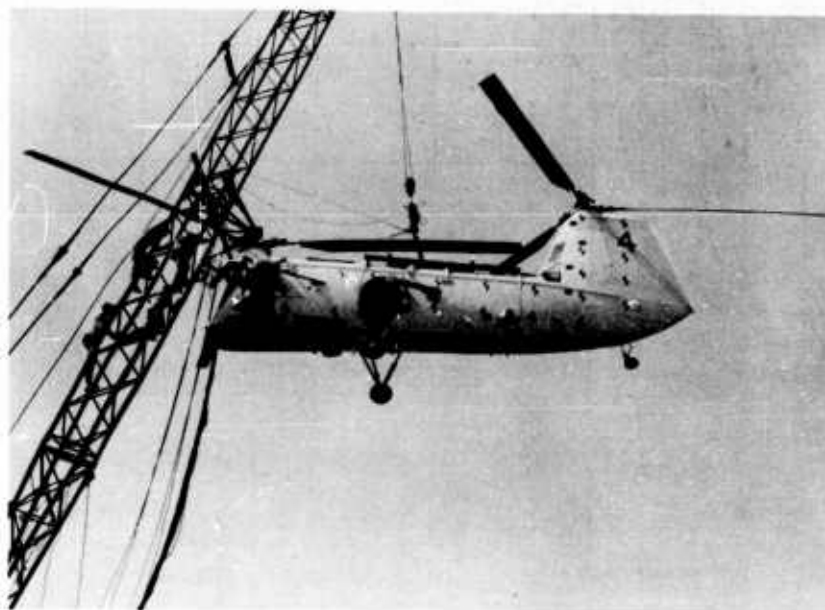


Figure 19. Method of Suspending HUP-2 Aircraft.

Approximately 40 channels of data were obtained during each test. These data were recorded on four oscillographs mounted on the rear deck of the crane and connected to the data pickups in the test articles through an umbilical cord. The oscillograph mounting arrangement is shown in Figure 20. Power for the oscillographs and the calibration unit was provided by a 2-1/2-kilowatt generator also mounted on the crane. Power for the airborne cameras was provided by NICAD batteries which were shock-mounted on board the test aircraft. Power for the ground cameras was provided by ground auxiliary power units.

In order to take maximum advantage of each aircraft as a test vehicle, certain additional experiments were conducted involving changes and modifications to seats, restraint systems, dummy positions, etc. This was done to the extent permitted by the number of useful data channels available in the instrumentation system.

TABLE I  
SPECIFIED AND ACTUAL TEST CONDITIONS

	Specified Conditions	Actual Test Conditions			
		Test No. 2 (H-25)	Test No. 3 (H-13)	Test No. 4 (H-25)	Test No. 5 (H-13)
	All Tests				
Flight Path	-40° (Down)	-48.1° (Down)	-51.2° (Down)	-55.8° (Down)	-49.43° (Down)
Flight Path Velocity Resultant	45 M.P.H. (66 F.P.S.)	39.4 M.P.H. (57.8 F.P.S.)	39.6 M.P.H. (56.6 F.P.S.)	37.8 M.P.H. (53.9 F.P.S.)	38.45 M.P.H. (56.4 F.P.S.)
Vertical Velocity	29 M.P.H. (42.5 F.P.S.)	29.1 M.P.H. (42.66 F.P.S.)	29.5 M.P.H. (43.3 F.P.S.)	29.2 M.P.H. (42.9 F.P.S.)	29.2 M.P.H. (42.8 F.P.S.)
Horizontal Velocity	35 M.P.H. (51.3 F.P.S.)	26.1 M.P.H. (38.2 F.P.S.)	24.35 M.P.H. (35.6 F.P.S.)	22.2 M.P.H. (32.6 F.P.S.)	25 M.P.H. (36.7 F.P.S.)
Pitch	9° Nose Up (T-2, T-4) 0° (T-3, T-5)	10° Nose Up	3° Nose Up	9° Nose Up	0°
Roll	0°	7° Left	3° Left	7° Right	0°
Yaw	0°	11° Left	Slightly to Left-Final Rest 35° Left	0°	3° Left
Wind	- -	5-10 Kts. 10 o'clock*	5-10 Kts. 10 o'clock*	5-10 Kts. Gusty 10 o'clock*	5 Kts. 6 o'clock
* From nose of aircraft					

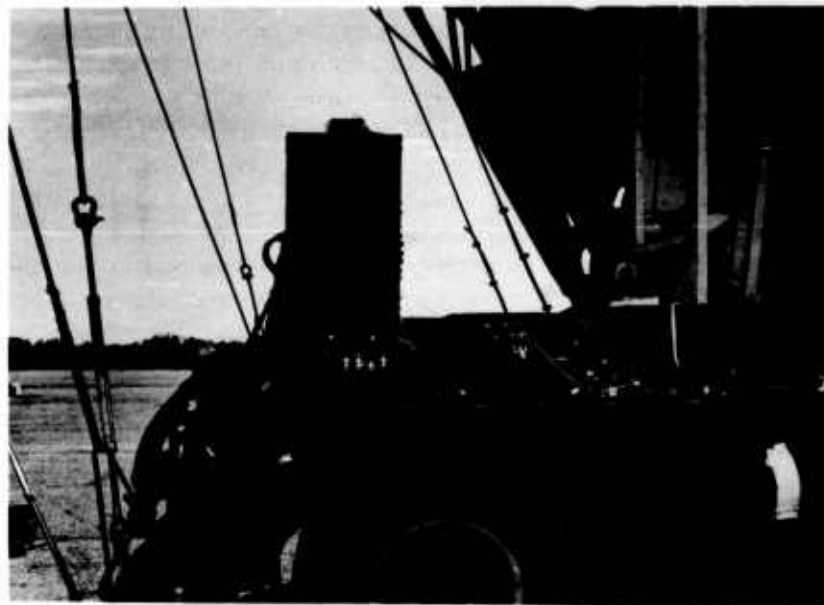


Figure 20. Oscillograph Mounting Arrangement for Test Vehicles.

Following is a brief description of the test setup and some of the preliminary findings for each of the four tests conducted.

TEST NO. 2 (HUP-2 HELICOPTER) - 14 JUNE 1961

Three anthropomorphic dummies were used in this test; one in the pilot's seat, left-front cockpit; one on a center-facing troop seat mounted on the left side wall in the cabin section of the aircraft; and one on a forward-facing troop seat mounted on the rear fire wall in the cabin section. A Mark XII range extender tank was placed in the copilot's seat in the right-front cockpit.

In most Army and civilian aircraft the restraint systems, seat belt, and shoulder harness are attached directly to the seats. During a crash, the load applied to the restraint system by the occupant is transmitted to the seat structure, further loading the seat. This arrangement contributes to failure of the seats. In addition, when the seat fails, the restraint systems become useless, and the seats with their occupants become projectiles. This situation has been experienced in many aircraft accidents and was verified in the H-25 test made in

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October 1960. The seat-belt and shoulder-harness loads measured in that test were extremely low (300-1,100 pounds) compared with the 3,000 pounds designed strength of the seat belts and shoulder harnesses. In Test No. 2, therefore, all restraint systems were anchored to basic aircraft structure, the purpose being to relieve the seat of some of the load experienced during the crash pulse and, more important, if the seat failed, the occupant would be retained in the immediate vicinity of his normal seated position rather than be thrown violently into some surrounding structure.

An examination of the seat-belt and shoulder-harness data obtained in Test 2 indicates that the loads experienced were from 50-75 percent higher on the average than those obtained in Test No. 1. They were not as high, however, as had been anticipated, due to seat failures and major buckling of the floor structure which resulted in considerable slack in the restraint systems during the crash.

In the October 1960 test of the H-25 helicopter, a dummy was seated on the standard military troop seat mounted on the left side wall of the cabin. During the crash the troop seat failed and the dummy impacted on the floor in a seated position. Acceleration measurements taken from the chest of the dummy, in the vertical axis, indicated 13G's at the time of seat failure and 56G's at the time of impact on the floor. Longitudinal and lateral (with respect to the axis of the dummy) accelerations recorded at almost the same time were 9 and 35G's, respectively. The effects correlated very well with accident experience in which troop seat failure is a frequent occurrence.

In Test No. 2, it was decided to restrain the dummy to prevent his impacting the floor after the troop seat failed and to measure the differences in accelerations. This was done by placing the dummy in a parachute harness and suspending the harness from the ceiling of the cabin, providing sufficient slack to permit the dummy to load the seat at impact. The seat again failed in the typical manner, but the dummy was restrained by the parachute harness in the general area occupied prior to impact. This prevented the dummy from falling through the seat and impacting on the floor as experienced in Test No. 1 and as experienced in actual accident cases. A preliminary examination of the data indicates that the vertical accelerations in the chest of this dummy were reduced by approximately 50 percent as compared to the data obtained from Test No. 1 in which he impacted on the floor.

In the October 1960 test of the H-25 helicopter, a Fiberglas Mark XII range extender tank was installed in the copilot's seat. During that crash, failures of the tank in the pan area of the seat and separation of the upper and inboard seams of the tank were experienced due to contact of the tank with the top window sill of the right-hand window of the aircraft and contact with the instrument console, causing massive spillage of the contents.

This range extender tank was subsequently redesigned, utilizing rubberized fabric-type material. The redesigned tank was installed in Test No. 2 and filled with 200 pounds of colored water to simulate its normal fuel load. During the crash the flexible tank contacted sharp metal structure because of the break-up of the floor structure in the cockpit of the aircraft, and again ruptured due to the cutting action of these sharp protruding items of broken floor. Massive fuel spillage again was experienced. Figures 21 through 26 show various views of the aircraft and components before and after the crash.

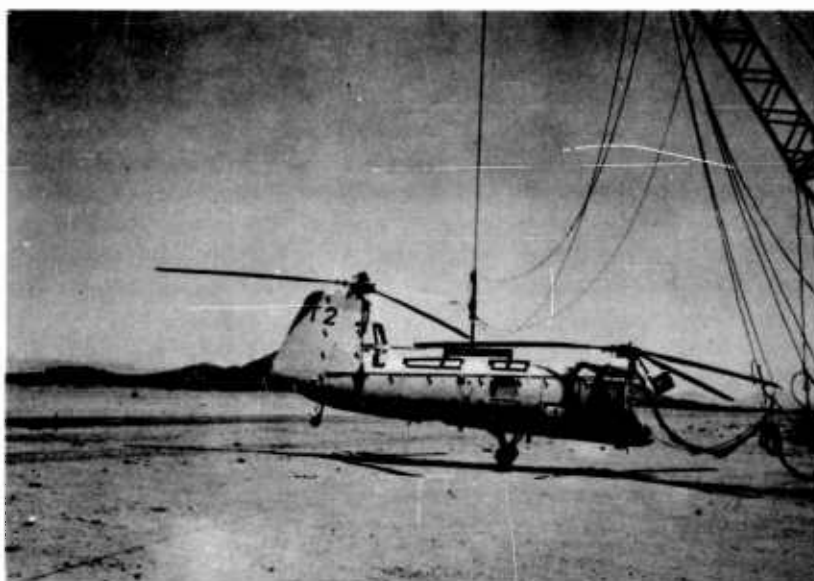


Figure 21. Overall View of Test Article (T-2)  
Before Drop.



Figure 22. Overall View of Test Article (T-2)  
After Drop.



Figure 23. Forward-Facing Rear Passenger (T-2)  
Before Drop.





Figure 24. Forward-Facing Rear Passenger (T-2)  
After Drop.

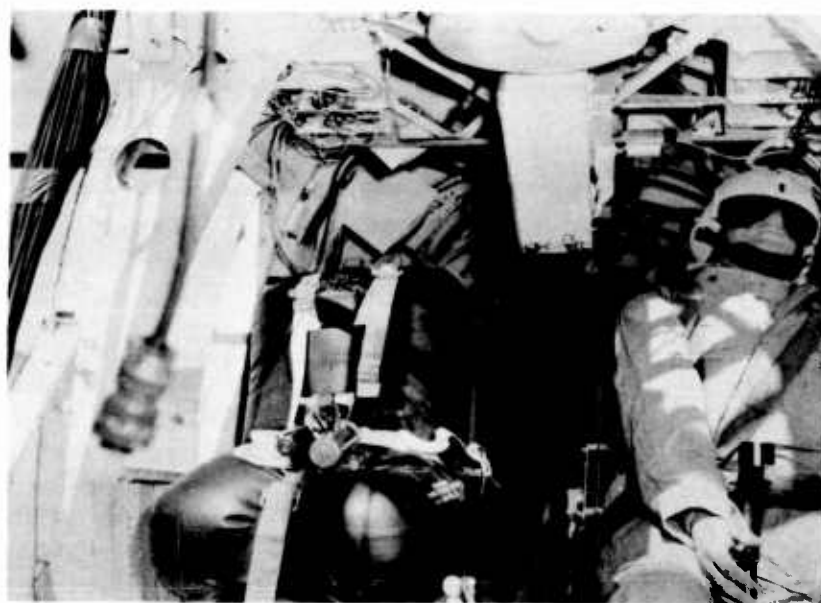


Figure 25. View of Cockpit (T-2) Before Drop.



Figure 26. View of Cockpit (T-2) After Drop.

TEST NO. 3 (H-13 HELICOPTER) - 17 JUNE 1961

In preparation for this test one anthropomorphic dummy was placed in the left-hand pilot's seat and a collapsible Mark XII range extender fuel tank filled with 200 pounds of colored water, to simulate its normal fuel load, was placed in the right-hand copilot's seat. The dummy in the pilot's seat was restrained by a normal seat belt installation without shoulder harness. The range extender tank was held in place by a seat-belt and shoulder-harness assembly.

A new design breakaway fuel tank assembly was provided by the United States Army Board for Aviation Accident Research for test on this aircraft. The fuel tank assembly consisted of two 18-gallon fuel tanks mounted parallel to the longitudinal axis of the aircraft on either side of the airframe at the engine center-line station. The tank support assembly was designed to break away at loads greater than 500 pounds. The concept being tested was one of having the breakaway fuel tanks tumble away from the aircraft during a crash to prevent massive fuel spillage in the immediate vicinity of the wreckage and to prevent the possibility of postcrash fire.

The test condition simulated an unsuccessful autorotation, and the conditions set up for this test closely paralleled the conditions used in Test Nos. 1 and 2. These conditions are set forth in Table 1.

Because of the lack of adequate support structure on this aircraft, only one airborne camera was mounted on the aircraft itself. This camera was mounted on the aft end of the tailboom of the helicopter. Twelve high-speed cameras were mounted in various locations on the ground to record the action during the crash.

The crane-run procedure and the release of the helicopter was a similar operation to that of Test Nos. 1 and 2. During the drop, the test aircraft was observed to yaw considerably to the left. The yaw angle, calculated from ground measurements made after the test, was 35 degrees. This yaw was probably caused by a gusty cross-wind blowing at that time, as indicated in Table 1.

During the crash, considerable structural damage was experienced with complete failure of the landing gear and various members of the fuselage structure. The seat structure crushed downward almost to cockpit floor level. The pilot dummy seat belt held; however, the dummy was thrown forward violently as he rotated over his seat belt. The seat belt and shoulder harness of the collapsible range extender fuel tank held; however, the lower forward end of the fuel tank ruptured when it came into contact with sharp broken metal, spilling fuel (colored water) over a large area.

The rod serving as support beams for the two bands around each of the breakaway fuel tanks received sufficient permanent bending to allow each tank to slip out of its support bracket. The turnbuckle lengths which had been necked down to fail at 500 pounds did not fail as planned. The design of the system required that the tanks develop a rotational force in their support saddles in order to develop the 500-pound force necessary to fail the turnbuckles. The rods serving as support beams bent and permitted the tanks to slip out of their brackets before the 500-pound force was developed. The left-hand tank did not clear the helicopter wreckage but lodged between the fuselage and the landing skid; the right-hand tank cleared the fuselage and came to rest at a location approximately 19 feet outboard of its location on the helicopter fuselage. Each tank received slight damage to the front end, causing some minor fuel seepage.

# WORK ITEM 10

Figures 27 through 30 show various views of the aircraft and components before and after the crash.

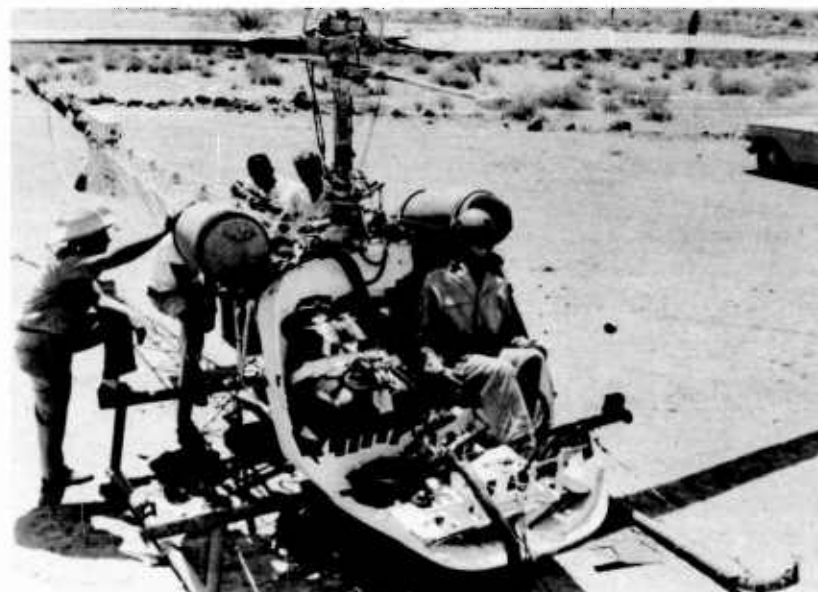


Figure 27. Overall View of Test Article (T-3)  
Before Drop.



Figure 28. Overall View of Test Article (T-3)  
After Drop.



Figure 29. Rear View (T-3) After Drop.

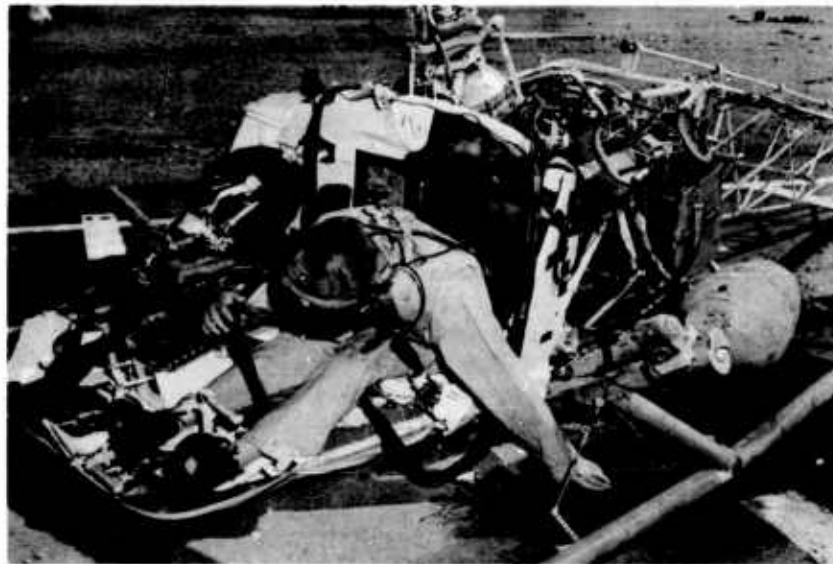


Figure 30. Close-up View of Cockpit Area (T-3) After Drop.

## WORK ITEM 10

### TEST NO. 4 (HUP-2 HELICOPTER) - 9 AUGUST 1961

In preparation for this test five anthropomorphic dummies were placed inside the helicopter. One was placed in the pilot seat; a second dummy was placed in a specially constructed copilot seat; the third dummy was seated on the floor of the passenger cabin on the right-hand side just aft of the copilot's seat; the fourth dummy was seated in an experimental troop seat located on the left-hand side of the passenger cabin facing sideward; and the fifth dummy was mounted on another experimental troop seat located in the rear of the passenger cabin facing forward.

The pilot and copilot dummy seat belts and shoulder harnesses were tied directly to basic structure under the cockpit floor instead of their being tied to the seat as are the seat belt and harness in the normal configuration. A specially designed seat was fabricated and installed in place of the normal copilot seat. The seat was designed to protect the copilot dummy from vertical accelerations exceeding 25G through the use of a five-layer block of paper honeycomb as a seat cushion (see discussion under Work Item 3).

Two experimental troop seats were constructed and installed in the helicopter in place of the standard side- and rear-mounted military specification troop seats. The design of these experimental troop seats was based on data obtained from the previous H-25 and HUP-2 tests conducted. The seats were designed to be suspended from the side wall and the roof of the helicopter rather than mounted to the floor where extremely high accelerations influence seat failure. They were also designed to provide the occupant with additional protection from crash forces by absorbing some of the energy of impact through the use of mechanical energy-absorption devices. The seats were located in such a manner to test the effectiveness of installations with occupants facing sideward and forward. Each dummy was restrained by using seat-belt and shoulder-harness tiedown restraint systems anchored to the basic structure of the aircraft (also see discussion under Work Item 9).

One dummy in the cabin section of the aircraft was seated on a cushion on the floor in order to simulate certain military operations in which the troops are being seated on the floor and to measure the accelerations that would be experienced by troops seated in this manner during an accident.

The structural damage experienced during the crash was very similar to that experienced in Test Nos. 1 and 2. During the crash the pilot seat support legs failed in a manner similar to the failures experienced in previous tests. However, the seat-belt and shoulder-harness tiedowns to the floor structure held, and the pilot and his seat remained in approximately the normal position occupied by the pilot. Some slack was experienced in the restraint system again, due to buckling of the basic structure to which the restraint system was attached and the stretch which is inherent in the webbing material of the shoulder harness and seat belt.

The seat support structure fabricated for the copilot remained relatively intact during the test, and the five-layer paper honeycomb block on which the copilot dummy was seated compressed considerably. More compression was experienced on the forward edge of the honeycomb, however, due to slack incurred in the restraint system. A preliminary examination of the acceleration measurements made in the pelvic regions of these two dummies reveals that the peak accelerations experienced in the pelvic region of the pilot dummy were on the order of 80 to 90G's while the peak accelerations recorded in the pelvic region of the copilot dummy mounted on the paper honeycomb block were on the order of 30 to 35G's. This is an indication of the manner in which high accelerations can be attenuated through the use of various energy-absorption materials in the seat designs. It was also interesting to note that the vertical accelerations measured in the dummy seated on the floor were of the same magnitude as those measured in the pelvic region of the pilot dummy seated on the standard pilot crew seat, i. e., 80 to 90G's. The accelerations experienced by the floor-seated dummy broke the cable which simulates the spinal cord.

The energy-absorption attenuators in both the experimental troop seats did not actuate as planned, resulting in very little stroke of the seat pan from this source. Some stroke was observed, however, as a result of the nylon supporter straps' stretching. The seat pans of both seats were ruptured. This was partially due to the fact that they had come in contact with the floor structure which broke upward under the seats and impacted against the seat pans during the crash. Preliminary examination of the accelerations experienced in the dummies mounted on the troop seats indicated that the experimental troop seat provided considerably more protection for the occupants of these seats than the normal troop seats such as were installed in Test Nos. 1 and 2. The additional protection given the passengers

#### WORK ITEM 10

of these seats was due to energy absorption of the impact from the nylon supporter strap's stretching, deformation of the seat pans, some overhead support structure deformation, and action of the energy absorption devices built into the upper support members of the seats. It is felt that this type of seat can, when the design is finalized, prove quite beneficial in reducing injuries resulting from crash impact.

Figures 31 through 36 show various views of the aircraft and components before and after the crash.



Figure 31. Overall View of Test Article (T-4)  
Before Drop.





Figure 32. Overall View of Test Article (T-4)  
After Drop.

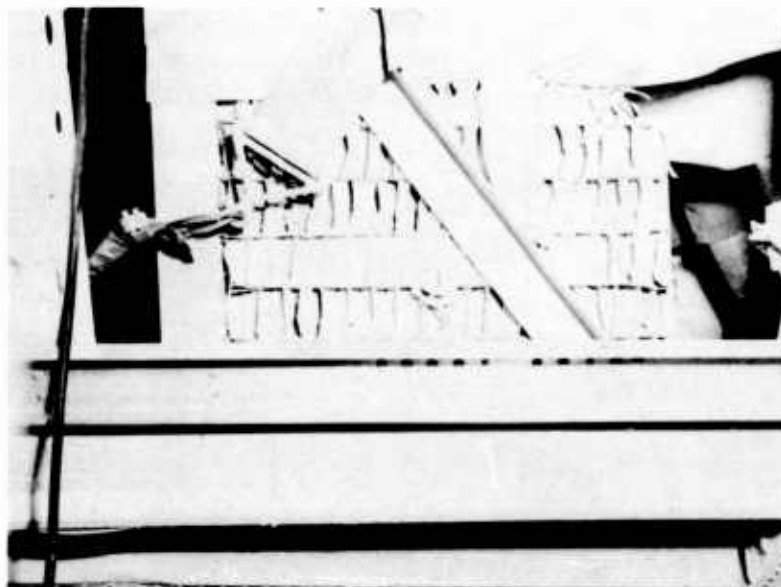


Figure 33. Paper Honeycomb Seat Pan (T-4)  
Before Drop.

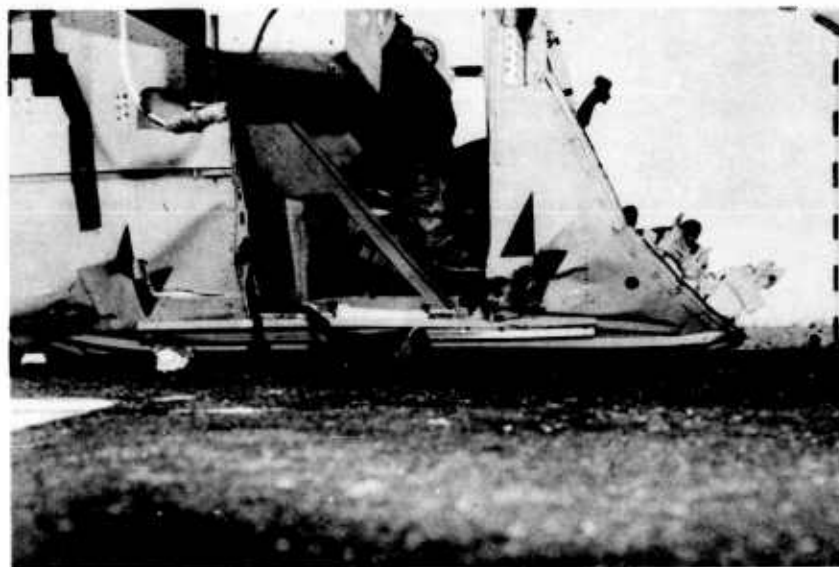


Figure 34. Paper Honeycomb Seat Pan (T-4)  
After Drop.



Figure 35. Forward-Facing Rear Passenger (T-4)  
Shown Positioned on Experimental Troop  
Seat Before Drop.

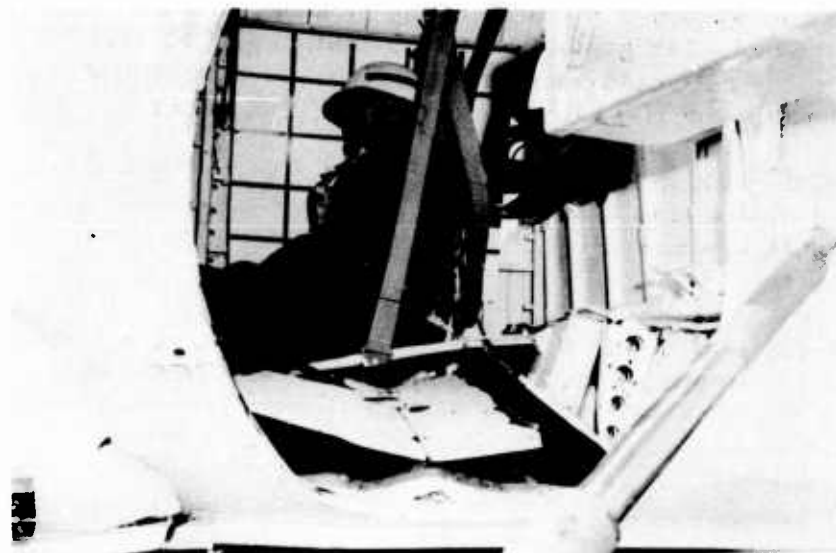


Figure 36. Forward-Facing Rear Passenger (T-4)  
Shown Positioned on Experimental  
Troop Seat After Drop.

TEST NO. 5 (H-13 HELICOPTER) - 3 AUGUST 1961

In preparation for this test one anthropomorphic dummy was placed in the left-hand pilot seat. A second dummy was placed in the right-hand copilot's seat, and another modified Mark XII range extender tank, filled with 200 pounds of colored water to simulate its normal fuel load, was placed between the pilot and copilot dummies. The pilot dummy and range extender tank were restrained to the seat by a normal seat-belt installation and shoulder harnesses which were tied to the basic structure. The copilot dummy was restrained only by seat belt.

A redesigned breakaway fuel tank assembly, similar to the assembly used in Test No. 3, consisted of two 18-gallon fuel tanks designed to break away at loads greater than 500 pounds; the tanks were installed on each side of the fuselage at the engine center-line station.

In this test the aircraft impacted at a point 3 feet to the right and 1 foot forward of target dead center. During the free fall the test specimen was observed to yaw to the left. The yaw angle, however, was very slight and was calculated to be only about 3 degrees.

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There was no apparent pitching of the vehicle, and the helicopter moved forward after ground contact a distance of 13 feet. The damage to the helicopter structure was in general similar to that experienced in the H-13 drop test conducted in June.

A preliminary examination of the acceleration and force data measured during this test indicates that the magnitudes and durations of these data are essentially the same as those measured in previous tests.

The seat-belt and shoulder-harness arrangement restraining the pilot dummy was effective and the dummy remained upright in the seat in a normal seated position. The seat, however, crushed considerably as did the seat in Test No. 3, almost to the floor level. The copilot dummy seat belt held also; however, the dummy rotated over his seat belt and was slumped forward and to the right in his seat after the crash.

The range extender tank which had been installed in this test had been previously modified with a heavy boot over the lower forward end of the tank for the purpose of preventing cutting action or rupture of the fuel cell by sharp jagged metal. The fuel tank did not tear as a result of contact with jagged metal; however, the pressure that developed inside the tank by the action of the liquid contents caused the vulcanized seam at the side of the tank to separate, and fuel again was spilled.

The breakaway fuel-tank-installation geometry was modified for this test prior to the drop by moving the center of gravity of each tank further outboard in order to assist the tanks in loading the breakaway turnbuckles and in clearing the helicopter structure at impact. The support saddles and the rods serving as support beams for the two bands around each tank failed and permitted the tanks to disengage in a manner similar to that experienced in Test No. 3. The tanks disengaged but did not clear the wreckage as had been anticipated. They came to rest between the landing skids and the fuselage. The left-hand tank was cracked on the forward end, resulting in some fuel leakage.

Figures 37 through 41 are various views of the aircraft before and after the crash.



Figure 37. Overall View of Test Article (T-5)  
Showing Breakaway Fuel Tanks  
Before Drop.

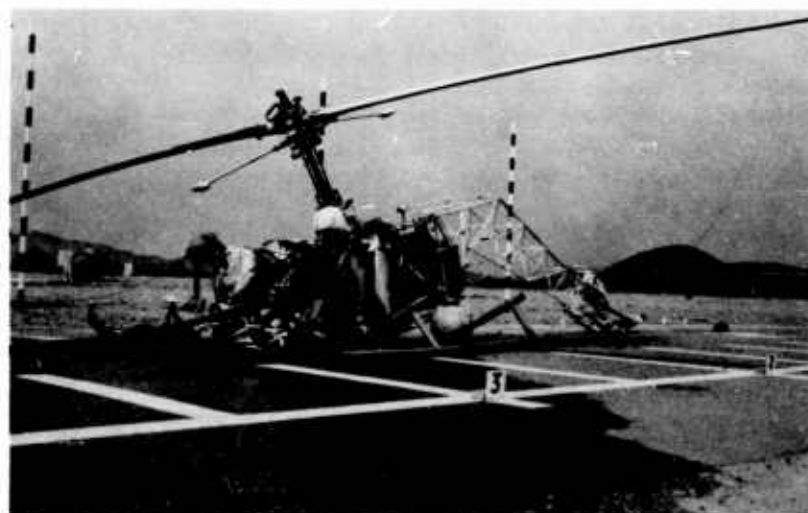


Figure 38. Overall View of Test Article (T-5)  
After Drop.



Figure 39. Close-up View of Test Article (T-5)  
After Drop.



Figure 40. Overall View of Test Article (T-5)  
After Drop (Left Side).



Figure 41. Overall View of Test Article (T-5)  
After Drop (Right Front Quarter).

#### SUMMARY

In summary, approximately 160 channels of useful electronic data were obtained from the four tests conducted. These data consisted of acceleration, force, and strain-gauge information. In addition, most of the photographic coverage was excellent and will be extremely useful in analyzing and interpreting the details of the action and in correlating this action with the acceleration and force measurements made.

Based upon a preliminary analysis of the data obtained during the four tests conducted, they are considered successful and have demonstrated that valid repeatable information can be obtained with the techniques used in these tests. The data are now being analyzed in detail and will be reported in future technical publications. The information obtained from the four tests conducted substantiate one of the conclusions made as a result of original Test No. 1, which is as follows:

"On the basis of this test for an H-25 aircraft accident involving an impact in a three-point attitude at 30 miles per hour in both the horizontal and vertical directions, peak accelerations may

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be expected to be of the order of:

### Airframe

Vertical acceleration at the floor, 100G  
Horizontal acceleration at the floor, 50G

### For a normally seated pilot or copilot

Vertical pelvic acceleration, 50-60G  
Longitudinal pelvic acceleration, 25-40G

### For a normally seated passenger

Vertical pelvic acceleration, 50G  
Longitudinal pelvic acceleration, 35G",  
(Reference 10, page 69).

The accelerations set forth above are applicable to both the H-25-  
and H-13-type helicopters.



POSTCRASH FIRE INVESTIGATION

Initially, the investigation of the U. S. Army postcrash aircraft fire problem concerned itself with the character and results of previous research related to this problem. It was found that a number of studies had been made on the causes of fire in both fixed- and rotary-wing aircraft. It was also found that a considerable amount of experimental work had been done on both crash fire inerting systems and crash resistant flammable fluid systems.

Statistical studies of fixed-wing aircraft accidents indicated that postcrash fire accidents are considerably more serious than non-fire accidents from the standpoint of occupant survival. One such study (Reference 17) of serious domestic and international scheduled air carrier accidents for the period January 1938 through June 1951 indicated an increase of approximately 20 percent in the number of fatalities in accidents involving fire. The study showed that crashes not followed by fire were fatal to 60.8 percent of the aircraft occupants, while in those accidents followed by fire, the fatality rate increased to 84.6 percent.

The increased use of rotary-wing aircraft in civilian and military operations resulted in speculation as to the seriousness of the survival problem in accidents involving rotary-wing aircraft. Because statistical records for fixed-wing accidents indicated that the fatality rate was affected by the occurrence of postcrash fire, a similar study (Reference 18) was conducted for rotary-wing aircraft accidents, based on records of 1,317 major rotary-wing accidents involving both military and civilian aircraft. Data developed in this study indicated that the fatality rate was over 40 percent higher in those accidents in which fire was involved. Fire was experienced in 8.7 percent of the accidents; the fatality rate in nonfire accidents was 3.7 percent, while in accidents followed by fire, the fatality rate was 42.5 percent. Of all the fatalities experienced, 60.4 percent occurred in those accidents followed by fire.

In 1960 the U. S. Army conducted a study (Reference 19) of helicopter accidents involving fire. The study was based on a 3-year period, 1 July 1957 to 30 June 1960, during which 579 major accidents were experienced of which 42 involved postcrash fire. These 42 accidents, however, accounted for 63 percent of the fatalities experienced in all of the 579 accidents involved. During the same reporting period, a comparable study (Reference 20) on fixed-wing

## WORK ITEM 11

accidents showed that less than 4 percent of the major fixed-wing accidents involved fire, indicating that the Army has approximately twice as many rotary-wing accidents involving fire as with fixed-wing accidents.

During the 3-year period of the study, the Army experienced 65 fatalities in rotary-wing accidents; 41, or 63 percent, of the fatalities occurred in accidents followed by fire. In comparing the fatalities experienced in postcrash fire accidents with nonfire accidents, it was found that one fatality was experienced in each accident followed by fire whereas only one fatality was experienced in 22 accidents not followed by fire. In other words, the chances for survival in nonfire accidents is approximately 22 times greater than in accidents involving fire. The added danger of fire following an accident is revealed by the fact that there were only 24 rotary-wing accidents in which burns were sustained. However, these 24 accidents produced 40 fatalities and 10 serious thermal injuries.

An examination of the various helicopter designs, particularly with reference to location of fuel cells, makes it apparent why the helicopter is more susceptible to postcrash fire and also why the fatality rates are higher. The fuel generally is carried near the center of gravity of rotary-wing aircraft as compared to fuel stored in the wings of fixed-wing aircraft. This places the fuel generally above, below, or in the immediate vicinity of the occupied section of rotary-wing aircraft in locations that are susceptible to puncture from below or to rupture of the fuel cells above the occupied section due to contact with ground obstacles or various parts of the structure. Since the center of gravity is a critical factor in rotary-wing aircraft, the power plant and transmission also are located in close proximity to the center of gravity and the fuel cells. Further, rotary-wing aircraft have very little crushable structure under the floor of the aircraft, as compared with most fixed-wing aircraft, with the result that high-impact forces are transmitted to fuel cells when located under the floor structure. All of these factors, in combination, make the helicopter very susceptible to postcrash fire in accidents where the forces experienced exceed the designed strength of the fuel cells and fuel system components.

A review of previous research revealed that fuel was most frequently the initial combustible ignited in flight and ground fires and was considered to be the most hazardous of the combustibles carried. Although electrical ignition was found to be the most

frequent flight fire ignition source by a small margin, the engine exhaust was concluded to be the most hazardous ignition source because it is necessarily located near the lubricating oil and fuel plumbing systems, and the resulting fires are more severe; the electrical ignition systems usually involve only the electrical insulation and result in small-volume fires.

As a result of initial studies conducted by the National Advisory Committee for Aeronautics (NACA), a number of fixed-wing airplanes were experimentally crashed to study the performance of crash-fire inerting systems developed by NACA (Reference 21). Previous experimental crashes indicated that the crash conditions imposed almost always resulted in fire. The experimental inerting systems were, therefore, exposed to conditions that would adequately test the ability to inert and de-energize the various ignition sources known to cause crash fire. The results of these experiments indicated that a properly designed crash-fire inerting system would prevent fires under the crash conditions imposed which almost always result in fire when no fire prevention system was used.

In developing a plan for the execution of this research program, the simplest and most readily obtainable solution to the postcrash fire problem in rotary-wing aircraft appears to be the development of suitable crash-fire inerting systems similar in concept to the systems tested by the NACA in the Cleveland Research Laboratory on fixed-wing aircraft. Some of the work performed by the NACA will be applicable to and can be used in the development of inerting systems in the proposed program. However, since the work done by the NACA involved fixed-wing aircraft only, many of the problems which will be encountered in the execution of the research program can be considered peculiar to rotary-wing aircraft.

A recommended postcrash fire research program, with initial attention to rotary-wing aircraft, calls for the development of an inerting and/or suppression system that will be completely automatic, actuated at moment<sup>o</sup> of impact, and functioning in a fail-safe manner. Four main components are suggested:

1. Fuel shut-off valves on fire walls and/or in the tubing between the carburetors and the engine cylinders; also, oil shut-off valves on each fire wall where applicable;

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2. Storage and plumbing systems in the engine compartments for discharging carbon dioxide into the diffuser housing induction systems or into the air inlets in the case of turbines;
3. Storage and plumbing systems for each engine to spray a coolant on the hot exhaust system; and
4. Switching arrangements for disconnecting the aircraft batteries and generators from the electrical power systems.

A Memorandum Report on this crash-fire investigation has been filed with USATRECOM, and plans are being formulated for the development and testing of this total system for a U. S. Army H-21 helicopter during 1961-62.

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2. Collection and coding of accident data;
3. Review of specifications and crash safety evaluation of aircraft;
4. Feasibility studies of dynamic testing devices;
5. Study of crash safety equipment and procedures;
6. Statistical and clinical analyses of mass accident data;
7. Liaison with groups and agencies on crash safety;
8. Training programs in crash injury investigation;
9. Feasibility study for remote control of an H-21 helicopter;
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7. Liaison with groups and agencies on crash safety;
8. Training programs in crash injury investigation;
9. Feasibility study for remote control of an H-21 helicopter;
10. Dynamic crash tests of four helicopters; and
11. Post crash fire studies.

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